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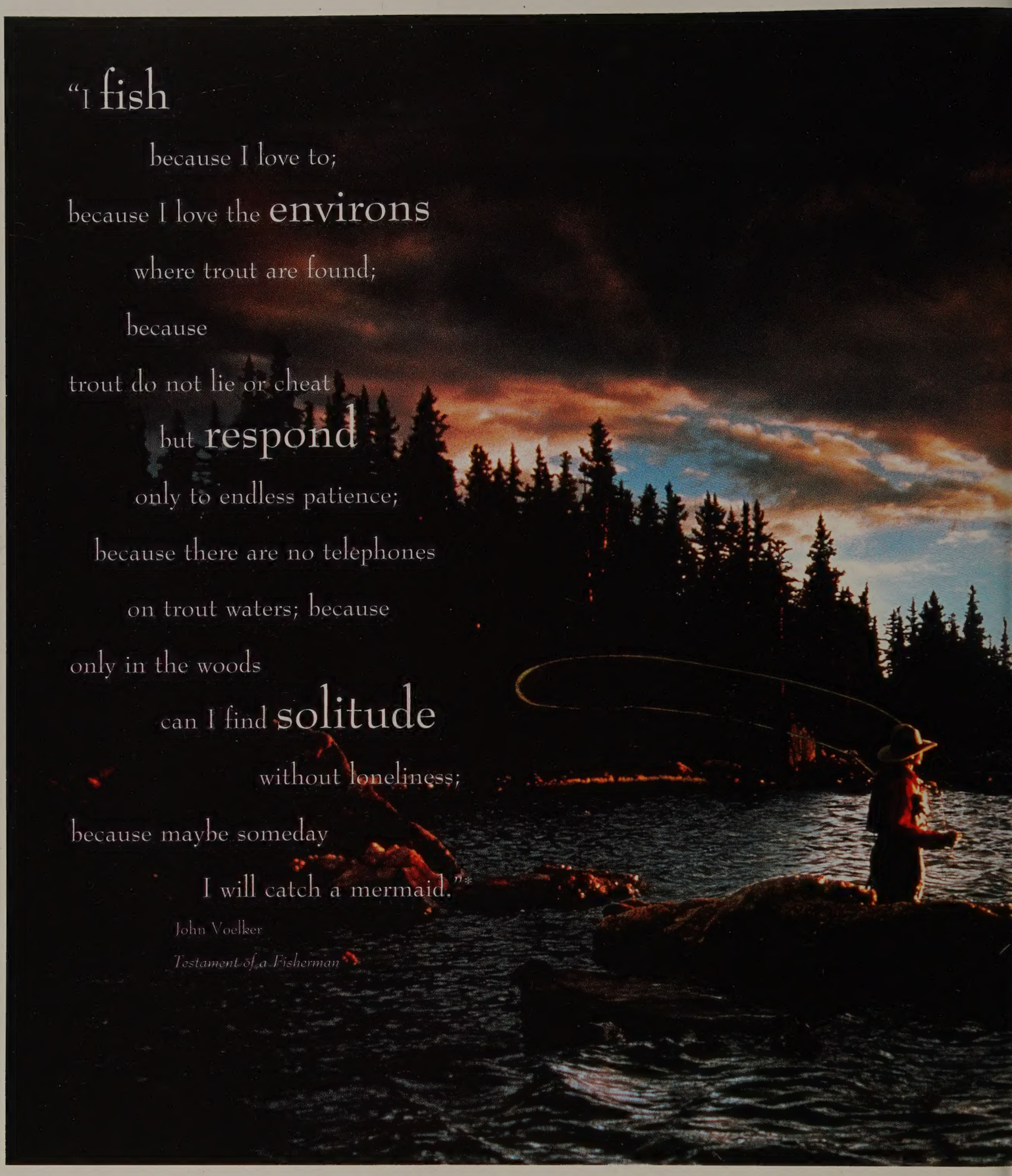

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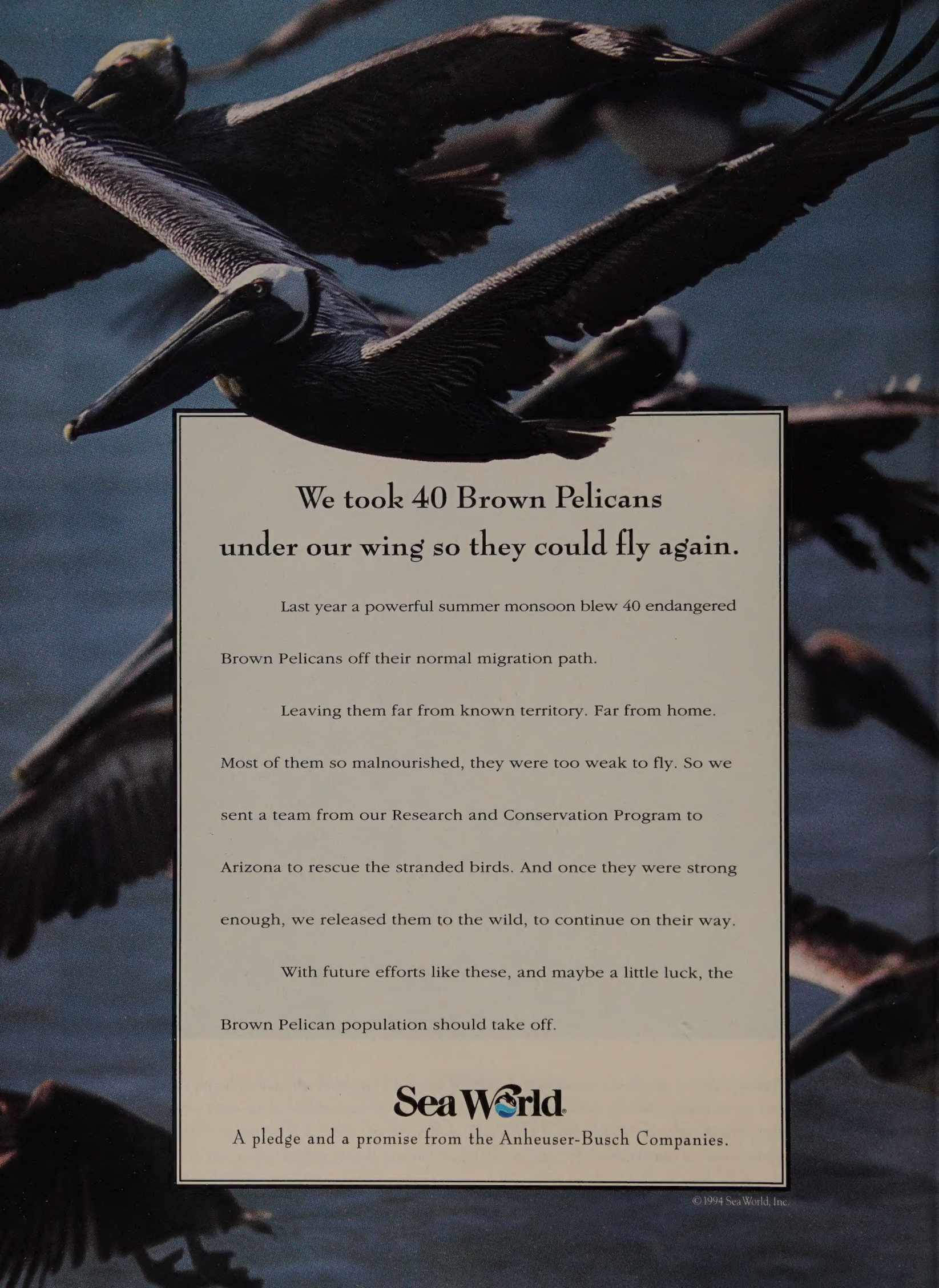

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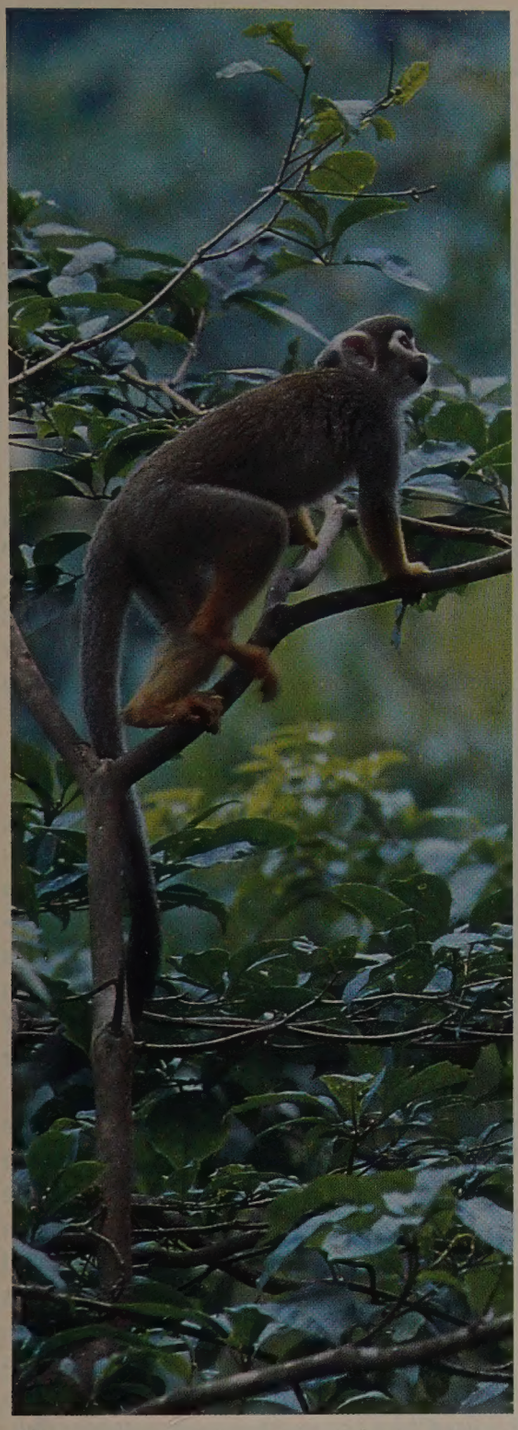

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NATURAL HISTORY

Vol. 103, No. 5, May 1994

COVER: *Poppies bloom in the Judean desert, where red flowers compete for the attentions of beetles. Story on page 52. Photograph by Allen Rokach.*

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NATURAL HISTORY
A monthly magazine of the American Museum of Natural History

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Natural History (ISSN 0028-0712) is published monthly by the American Museum of Natural History, Central Park West at 79th Street, New York, N.Y. 10024. Subscriptions: $28.00 a year. In Canada and all other countries: $37.00 a year. Second-class postage paid at New York, N.Y. and at additional mailing offices. Send subscription orders and undeliverable copies to the address below. Membership and subscription information: Write to address below or call (800) 234-5252 if urgent. Postmaster: Send address changes to *Natural History*, Post Office Box 5000, Harlan IA 51537-5000.

Printed on recycled paper in the USA

LETTERS

THE BATS OF WINTER

Thanks for Bernd Heinrich's fine article and accompanying photographs on winter moths ("Some Like It Cold," February 1994). Being active in winter certainly helps moths avoid bats in cold climates such as that of Vermont. In southern New Jersey where I study winter moths, however, temperatures are often well above freezing on winter evenings at dusk, and big brown bats are virtually always foraging when these moths are flying. Since very few insects besides small flies are active here between December and February, the calorie-rich winter moths may be at even greater risk from bats in January than they are in July.

Another note: the critical need to have larval hatching timed to coincide with budbreak, rather than avoidance of birds, probably affected the evolution of early-spring egg-laying in these and many other moth species.

DALE SCHWEITZER
Port Norris, New Jersey

STILL LOOKING

Regarding the article "Bagging the Little Green Men" ("Celestial Events," February 1994), I am happy to report that SETI (Search for Extraterrestrial Intelligence) is very much alive and well. While it is true that Congress has directed NASA to abandon its attempts to detect radio transmissions from other solar systems, the SETI Institute's efforts to raise private money to keep the search alive have met with success—we are more than halfway to our goal of $7.3 million. These funds will enable us first to modify and improve the digital receivers lent to us by NASA and then to deploy this equipment at the Parkes radio observatory in New South Wales, Australia, for Southern Hemisphere observations in 1995. We then plan to move the receiving equipment to the Northern Hemisphere, beginning with the 1,000-foot-diameter radiotelescope at Arecibo, Puerto Rico. We expect observations to continue into the next millennium. I look forward to a day, perhaps not far off, when we hear the first evidence that we are not alone in the universe.

FRANK D. DRAKE
President, SETI Institute
Mountain View, California

CONVERGENT CHEMICAL EVOLUTION?

In "Stinking Birds and Burning Books" ("Nature's Infinite Book," January 1994), Jared Diamond discusses the recent recognition that certain jay-sized New Guinea birds called pitohuis share a potent defensive toxin (homobatrachotoxin) with Colombian poison-dart frogs. He goes on to suggest that this is a remarkable case of "convergent evolution at the molecular level."

An analogous case suggests that the convergent evolution may rather be the ability of both organisms to safely culture toxin-producing bacteria. The infamous tetrodotoxin, which almost dispatched James Bond in *From Russia with Love,* is an example of this latter convergence. Tetrodotoxin got its name from the pufferfish (of the family Tetradontidae), which is used in *fugu,* the Japanese culinary delicacy. But it has subsequently been found in many other animals, including unrelated fishes, frogs and salamanders, gastropods, crabs, starfish, and the beautiful blue-ringed octopuses of southern oceans. These animals can harbor bacteria that produce the toxin, and indeed one can rear toxin-free pufferfish with appropriate precautions. The pitohuis and the poison-dart frogs may well share an ability to culture toxin-producing bacteria on their skins, and the presence or absence of such bacteria would explain the range of toxicities noted by Diamond in different parts of the birds' range.

An important corollary of such symbioses is that the hosts must be immune to the bacterial poisons. Both homobatrachotoxin and tetrodotoxin bind to sodium channels in the membranes of susceptible

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Flying squirrels: two ghosts in a snowstorm
Seiichi Meguro; Nature Production

animal cells; perhaps changes in the proteins that confer resistance demonstrate "convergent evolution at the molecular level."

ROGER PRINCE
Pittstown, New Jersey

INCONSISTENT SEXUAL POLITICS

I have just belatedly received the November 1993 issue of *Natural History* and cannot fathom how you managed to publish Stephen Jay Gould's "The Sexual Politics of Classification" and "A Goddess Unveiled," by Harry Y. McSween, Jr., in the same issue. Gould's article is almost comically sensitive to gender stereotyping in the nature writings of past centuries. Yet a few pages farther on, readers are expected to accept a contemporary author's use of a metaphor in which the planet Venus is a seemingly beautiful goddess who, when stripped naked by science, is revealed as an "old floozy" with pimples, wrinkles, blemishes, blisters, and sores that suggest an interesting past. The latter is far more vicious an image than anything quoted by Gould.

EILEEN FIELDING
Chesterton, Indiana

EVOLUTION OF CAKES

In her sidebar, "The Twelfth Cake" (in "The Rise of the British Wedding Cake," December 1993), Bridget Ann Henisch laments the collapse of the Christmastime and Epiphany celebrations by the end of the last century. Actually, such observances continued in southern Louisiana. Today, the traditions and games linger in the form of King Cakes, which begin to appear with the Twelfth Night parties that launch the Mardi Gras season.

FREDERICK STIELOW
New Orleans, Louisiana

Simon Charsley's article on wedding cakes brought to mind the words of *The Woman's Home Companion Cookbook,* published in New York by Colliers in 1943.

On page 750 we are advised:

> The true wedding cake is a rich fruit cake. It may be decorated and placed on a reception table or it may be packed in small boxes to hand to the guests as they leave. In the latter case, a bride's cake may be used on the table. The bride's cake is usually a white cake, pound cake, sponge cake, or light fruit cake. Frequently the true wedding cake is dispensed with and only the bride's cake is used.
>
> Decorate with lilies of the valley....an attractive addition is a series of streamers of lilies of the valley running from top to bottom. Surround the cake with real flowers....

As the baker on the vessel *Inspiration,* I use this cookbook a lot, but I am not going to make such a cake.

WILLIAM F. STEAGALL, SR.
La Paz, Mexico

AN EXTRA GHOST

January's "Natural Moment" photo ("Ghost in a Snowstorm") by Seiichi Meguro was a delight, and the patience of the photographer seems to have been well rewarded. However, you may have missed a second tiny ghost in the snowy scene—another wide-eyed flying squirrel attached to the trunk of a tree, below and to the viewer's left of the featured performer. I feel this apparition should have been given equal billing.

JAMES RANDI
Plantation, Florida

ERRATA: In the April 1994 issue, the article on Caribbean dugongs, "West Indian Tuskers," states that modern dugongs uproot sea grasses with their tusks. This, an editorial extrapolation, is in error. According to author Daryl Domning, dugongs (like manatees) can uproot small rhizomes of sea grasses with their snouts; the tusks are used in combat. We apologize for the mistake.

Clear Creek, shown on page 42 in our November 1993 issue ("Damming the Past"), flows into the Arkansas River, not the Colorado. *Natural History* regrets the editorial error, which several readers brought to our attention.

Sculptures (clockwise): Blue Jay, Hummingbird, Chickadee, Kinglet, Oriole.

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Hooking Leviathan by Its Past

Two tales of tails confirm the theory of the whale's return to the sea

by Stephen Jay Gould

The landscape of every career contains at least a few crevasses, and usually a more extensive valley or two—for every Ruth's bat, a Buckner's legs; for every lopsided victory at Agincourt, a bloodbath at Antietam. Darwin's first edition of *Origin of Species* contains some wonderful insights and magnificent lines, but this masterpiece also includes a few notable clinkers. Darwin became most embarrassed about the following passage, curtailed and largely expunged from following editions of his book:

> In North America the black bear was seen by Hearne swimming for hours with widely open mouth, thus catching, like a whale, insects in the water. Even in so extreme a case as this, if the supply of insects were constant, and if better adapted competitors did not already exist in the country, I can see no difficulty in a race of bears being rendered, by natural selection, more aquatic in their structure and habits, with larger and larger mouths, till a creature was produced as monstrous as a whale.

Why did Darwin become so chagrined about this passage? His hypothetical tale may be pure speculation and conjecture, but the scenario is not entirely absurd. Darwin's discomfort arose, I think, from his failure to follow a scientific norm of a more sociocultural nature. Scientific conclusions supposedly rest upon facts and information. Speculation is not entirely taboo, and may sometimes be necessary *faute de mieux.* But when scientists propose truly novel and comprehensive theories—as Darwin tried to do in advancing natural selection as the primary mechanism of evolution—they need particularly good support, and invented hypothetical cases just don't supply sufficient oomph for crucial conclusions.

Natural selection (or the human analogue of differential breeding) clearly worked at small scale—in the production of dog breeds and strains of wheat, for example. But could such a process account for the transitions of greater scope that set our concept of evolution in the fullness of time: the passage of reptilian lineages to birds and mammals; the origin of humans from an ancestral stock of apes? For these larger changes, Darwin could provide little direct evidence, for a set of well-known and much lamented reasons based on the extreme spottiness of the fossil record.

Some splendid cases began to accumulate in years following the *Origin of Species,* most notably the discovery in 1861 of *Archaeopteryx,* an initial bird chock-full of reptilian features, and the first findings of human fossils late in the nineteenth century. But Darwin had little to present in his first edition of 1859, and he tried to fill this factual gap with hypothetical fables about swimming bears eventually turning into whales—a fancy that yielded far more trouble in easy ridicule than aid in useful illustration. Just two years after penning his bear-to-whale tale, Darwin lamented in a letter to a friend (James Lamont, February 25, 1861), "It is laughable how often I have been attacked and misrepresented about this bear."

The supposed lack of intermediary forms in the fossil record remains the fundamental canard of current antievolutionism. Such transitional forms are scarce, to be sure, and for two sets of good reasons—geological (the gappiness of the fossil record) and biological (the episodic nature of evolutionary change, including patterns of punctuated equilibrium and transition within small populations of limited geographic extent). But paleontologists have discovered several superb examples of intermediary forms and sequences, more than enough to convince any fair-minded skeptic about the reality of life's physical genealogy.

The first "terrestrial" vertebrates retained six to eight digits on each limb (more like a fish paddle than a hand), a persistent tail fin, and a lateral line system for sensing sound vibrations underwater. The anatomical transition from reptiles to mammals is particularly well documented in the key anatomical change of jaw articulation to hearing bones. Only one bone, called the dentary, builds the mammalian jaw, while reptiles retain several small bones in the rear part of the jaw. We can trace, through a lovely sequence of intermediates, the reduction of these small reptilian bones and their eventual disappearance or exclusion from the jaw, including the remarkable passage of the reptilian articulation bones into the mammalian middle ear (where they become our malleus and incus, or hammer and anvil). We have even found the transitional form that creationists often proclaim inconceivable in theory—for how can jawbones become ear bones if intermediaries must have unhinged jaws before the new joint forms? The transitional species maintains a double jaw joint, with both the old articulation of reptiles (quadrate to articular bones) and the new connection of mammals (squamosal to dentary) already in place! Thus, one joint could be lost, with passage of its bones into the ear, while the other articulation continued to guarantee a properly hinged jaw.

Still, our creationist incubi, who would never let facts spoil a favorite argument, refuse to yield, and continue to assert the absence of *all* transitional forms by ignoring those that have been found and continuing to taunt us with admittedly frequent examples of absence. Darwin's difficulty

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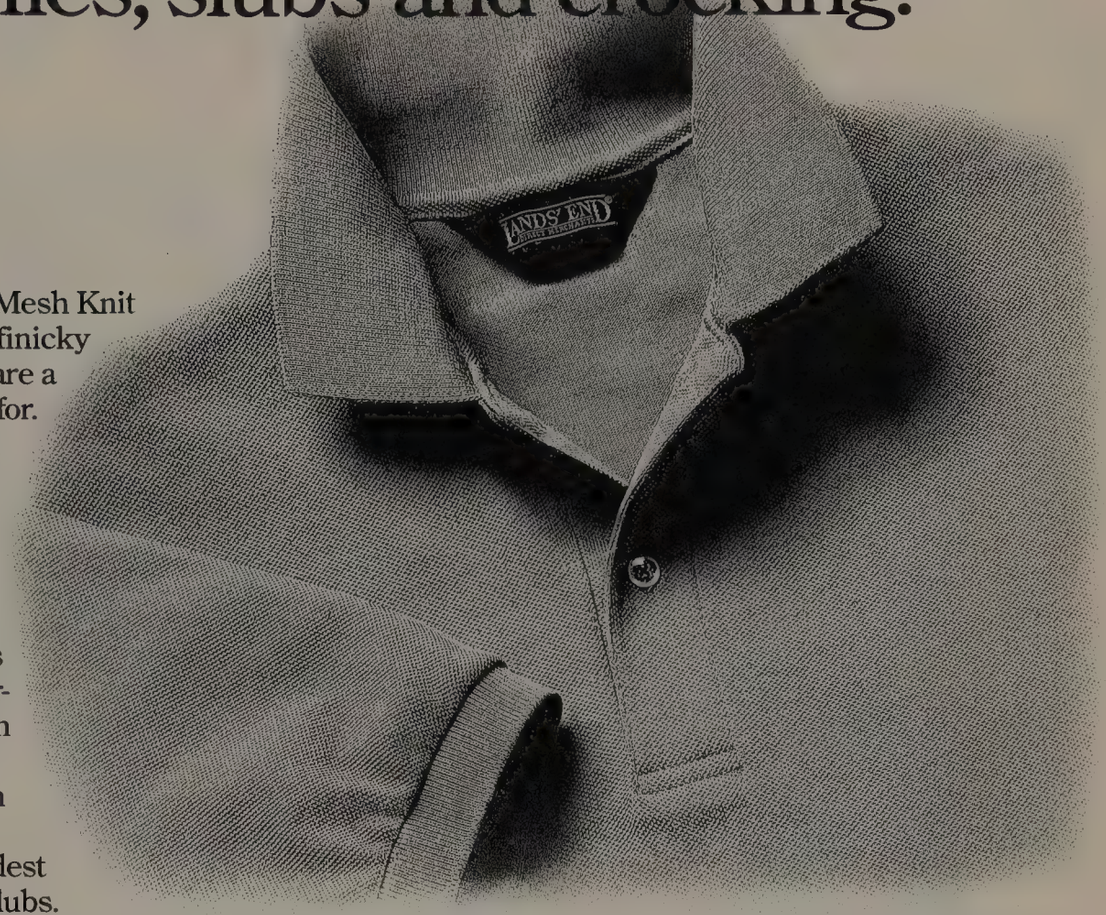

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with the origin of whales remains a perennial favorite. God's taunt to Job might be sounded again: "canst thou draw out leviathan with an hook?" (The biblical leviathan is usually interpreted as a crocodile, but many alternative readings favor whales.)

Every creationist book on my shelf cites the actual absence and inherent inconceivability of transitional forms between terrestrial mammals and whales. Alan Haywood, for example, writes (*Creation and Evolution,* Triangle Books, 1985):

> Darwinists rarely mention the whale because it presents them with one of their most insoluble problems. They believe that somehow a whale must have evolved from an ordinary land-dwelling animal, which took to the sea and lost its legs.... A land mammal that was in process of becoming a whale would fall between two stools—it would not be fitted for life on land or at sea, and would have no hope of survival.

Duane Gish, creationism's most ardent debater, makes the same argument in his more colorful style (*Evolution: The Challenge of the Fossil Record,* Creation Life Publishers, 1985):

> There simply are no transitional forms in the fossil record between the marine mammals and their supposed land mammal ancestors.... It is quite entertaining, starting with cows, pigs, or buffaloes, to attempt to visualize what the intermediates may have looked like. Starting with a cow, one could even imagine one line of descent which prematurely became extinct, due to what might be called an "udder failure."

The most "sophisticated" (I should really say "glossy") of creationist texts, *Of Pandas and People,* by P. Davis, D. H. Kenyon, and C. B. Thaxton (Haughton Publishing, 1989), says much the same, but more in the lingo of academese:

> The absence of unambiguous transitional fossils is strikingly illustrated by the fossil record of whales.... If whales did have land mammal ancestors, we should expect to find some transitional fossils. Why? Because the anatomical differences between whales and terrestrial mammals are so great that innumerable in-between stages must have paddled and swam the ancient seas before a whale as we know it appeared. So far these transitional forms have not been found.

Three major groups of mammals have returned to the ways of distant ancestors in their seafaring modes of life (while smaller lineages within several other mammalian orders have become at least semiaquatic, often to a remarkable degree, as in river and sea otters): the suborder Pinnipedia (seals, sea lions, and walruses) within the order Carnivora (dogs, cats, and Darwin's bears among others); and two entire orders—the Sirenia (dugongs and manatees) and Cetacea (whales and dolphins). I confess that I have never quite grasped the creationists's point about inconceivability of transition—for a good structural (although admittedly not a phylogenetic) series of intermediate anatomies may be extracted from these groups. Otters have remarkable aquatic abilities, but retain fully functional limbs for land. Sea lions are clearly adapted for water, but can still flop about on land with sufficient dexterity for ice floes, breeding grounds, and circus rings.

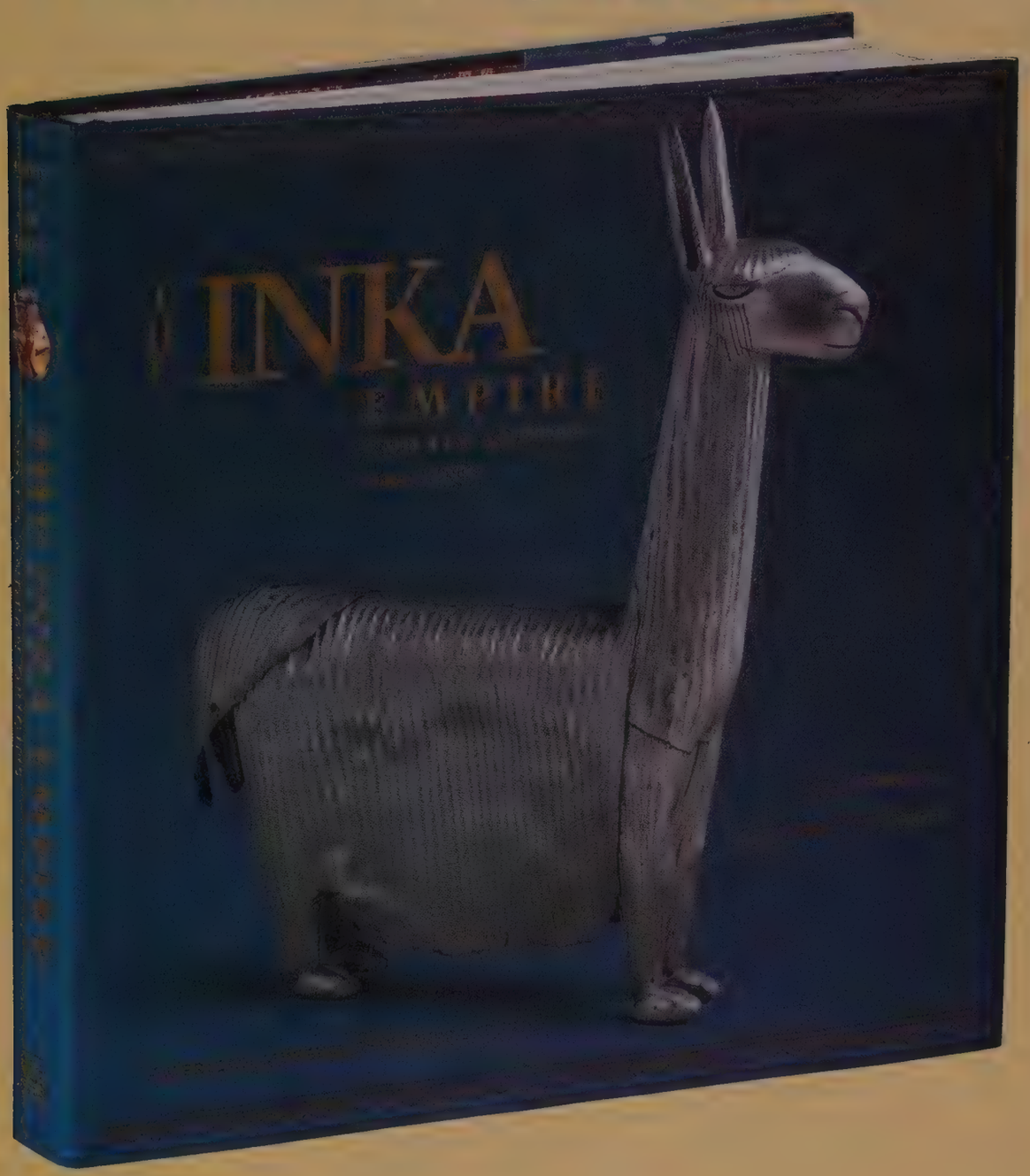
But I admit, of course, that the transition to manatees and whales represents no trivial extension, for these fully aquatic mammals propel themselves by powerful, horizontal tail flukes and have no visible hind limbs at all—and how can a lineage both develop a flat propulsive tail from the standard mammalian length of rope and then forfeit the usual equipment of back feet so completely? (Sirenians have lost every vestige of back legs; whales often retain tiny, splintlike pelvic and leg bones, but no foot or finger bones, embedded in musculature of the body wall, but with no visible expression in external anatomy.)

The loss of back legs and the development of flukes, fins, and flippers by whales therefore stands as a classic case of a supposed cardinal problem in evolutionary theory—the failure to find intermediary fossils for major anatomical transitions or even to imagine how such a bridging form might look or work. Darwin acknowledged the issue by constructing a much criticized fable about swimming bears, instead of presenting any evidence at all, when he tried to conceptualize the evolution of whales. Modern creationists continue to use this example and stress the absence of intermediary forms in this supposed (they would say impossible) transition from land to sea.

Goethe told us to "love those who yearn for the impossible." But Pliny the Elder, before dying of curiosity by straying too close to Vesuvius at the worst of all possible moments, urged us to treat impossibility as a relative claim: "How many things, too, are looked upon as quite impossible until they have been actually effected." Armed with such wisdom of human ages, I am absolutely delighted to report that our usually recalcitrant fossil record has come through in exemplary fashion. During the past fifteen years, new discoveries in Africa and Pakistan have added greatly to our paleontological knowledge of the earliest history of whales. The embarrassment of past absence has been replaced by a bounty of new evidence—and by the sweetest series of transitional fossils an evolutionist could ever hope to find. Truly, we have met the enemy and he is now ours. Moreover, to add blessed insult to the creationists's injury, these discoveries have arrived in a gradual and sequential fashion—a little bit at a time, step by step, from a tentative hint fifteen years ago to a remarkable smoking gun early in 1994. Intellectual history has

"I love my kids, but these Mother's Day visits do have their drawbacks."

THE INKA EMPIRE AND ITS ANDEAN ORIGINS



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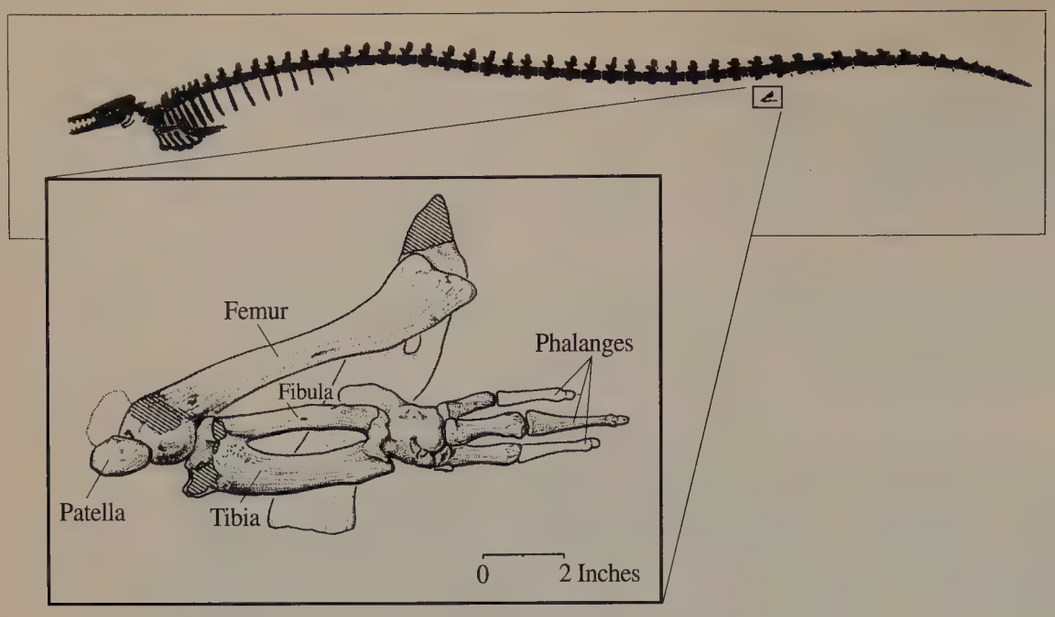


A fifty-foot Eocene whale, Basilosaurus isis, *from the Zeuglodon Valley of Egypt, had tiny hind limbs, shown in detail above.*
Adapted from *Science,* vol. 249, 13 July 1990

matched life's genealogy by spanning the gaps in sequential steps. Consider the four main events in chronological order.

Case One: Discovery of the oldest whale. Paleontologists have been fairly confident, since Leigh Van Valen's demonstration in 1966, that whales descended from mesonychids, an early group of primarily carnivorous running mammals that spanned a great range of sizes and habits from eating fishes at river edges to crushing bones of carrion. Whales must have evolved during the Eocene epoch, some fifty million years ago, because late Eocene and Oligocene rocks already contain cetaceans so fully marine that we must judge them as past any point of intermediacy.

In 1983, my colleague Phil Gingerich, of the University of Michigan, along with N. A. Wells, D. E. Russell, and S. M. Ibrahim Shah ("Origin of Whales in Epicontinental Remnant Seas," *Science,* vol. 220, pp. 403–406), reported their discovery of the oldest whale, named *Pakicetus* to honor its country of present residence, from Middle Eocene sediments some fifty-two million years old in Pakistan. In terms of intermediacy, one could hardly have hoped for more from the limited material available, for only the skull of *Pakicetus* has been found. The teeth strongly resemble those of terrestrial mesonychids, as anticipated, but the skull, in feature after feature, clearly belongs to the developing lineage of whales.

Both the anatomy of the skull, particularly in the ear region, and its environment of deposition testify to transitional status. The ears of modern whales contain modified bones and passageways that permit directional hearing in the dense medium of water. They have also evolved enlarged sinuses that can be filled with blood to maintain pressure during diving. The skull of *Pakicetus* lacks both these features, and this first whale could neither dive deeply nor hear directionally with any efficiency in water.

In 1993, J. G. M. Thewissen and S. T. Hussain ("Origin of Underwater Hearing in Whales," *Nature,* vol. 361, pp. 444–45) affirmed these conclusions and added more details on the intermediacy of skull architecture in *Pakicetus*. Modern whales do much of their hearing through their jaws, as sound vibrations pass through the jaw to a "fat pad" (the technical literature, for once, invents no jargon and employs the good old English vernacular in naming this structure) and thence to the middle ear. Terrestrial mammals, by contrast, detect most sound through the ear hole (called the "external auditory meatus," in more refined language). Since *Pakicetus* lacked the enlarged jaw hole that holds the fat pad, this first whale probably continued to hear through the pathways of its terrestrial ancestors. Gingerich concluded that "the auditory mechanism of *Pakicetus* appears more similar to that of land mammals than it is to any group of extant marine mammals."

As for place of discovery, Gingerich and colleagues found *Pakicetus* in river sediments bordering an ancient sea (*see* "The Whales of Tethys," *Natural History,* April 1994)—an ideal place for the first stages of such an evolutionary transition (and a good explanation for lack of diving specializations if *Pakicetus* inhabited the mouths of rivers and adjacent shallow seas). They judged *Pakicetus* as "an amphibious stage in the gradual evolutionary transition of primitive whales from land to sea.... *Pakicetus* was well equipped to feed on fishes in the surface waters of shallow seas, but it lacked auditory adaptations necessary for fully marine existence."

Verdict: In terms of intermediacy, one could hardly hope for more from the limited material of skull bones only. But the limit remains severe, and the results therefore inconclusive. We know nothing of the limbs, tail, or body form of *Pakicetus,* and therefore cannot judge its transitional status in these key features of anyone's ordinary conception of a whale.

Case Two: Discovery of the first complete hind limb in a fossil whale. In the most famous mistake of early American paleontology, Thomas Jefferson, while not engaged in other pursuits usually judged more important, misidentified the claw of a fossil ground sloth as that of a lion. My prize for second worst error must go to R. Harlan who, in 1834, named a marine fossil vertebrate *Basilosaurus* in the *Transactions of the American Philosophical Society. Basilosaurus* means "king lizard," but Harlan's creature is an early whale. Richard Owen, England's greatest anatomist, corrected Mr. Harlan before the decade's end, but the name sticks—and must be retained by the official rules of zoological nomenclature. (Remember that the Linnaean naming system is a device for information retrieval, not a guarantor of appropriateness. The rules require that each species have a distinctive name, so that data can be associated unambiguously with a stable tag. Often, and inevitably, the names originally given become literally inappropriate for the unsurprising reason that scientists make frequent mistakes, and that new discoveries modify old conceptions. If we had to change names every time our ideas about a species altered, taxonomy would devolve into chaos. So *Basilosaurus* will always be *Basilosaurus* because Harlan followed the rules when he gave the name. And we do not change ourselves to *Homo horribilis* after Auschwitz, or to *Homo ridiculosis* after Tonya Harding—but remain, however dubiously, *Homo sapiens,* now and into whatever forever we allow ourselves.)

Basilosaurus, represented by two species, one from the United States and the other from Egypt, is the "standard" and best-known early whale. A few fragments

of pelvic and leg bones had been found before, but not enough to know whether *Basilosaurus* bore working hind legs—the crucial feature for our usual concept of a satisfying intermediate form in both anatomical and functional senses.

In 1990, Phil Gingerich, B. H. Smith, and E. L. Simons reported their excavation and study of several hundred partial skeletons of the Egyptian species *B. isis,* which lived some five to ten million years after *Pakicetus*. In an exciting discovery, they reported the first complete hind limb skeleton found in any whale—a lovely and elegant structure (put together from several partial specimens), including all pelvic bones, all leg bones (femur, tibia, fibula, and even the patella, or knee cap), and nearly all foot and finger bones, right down to the phalanges (the finger bones) of the three preserved digits ("Hind Limbs of Eocene *Basilosaurus*: Evidence of Feet in Whales," *Science,* vol. 249, pp. 154–57).

This remarkable find might seem to clinch our proof of intermediacy, but for one small problem. The limbs are elegant, but tiny (*see* accompanying figure of *B. isis* on page 12), a mere 3 percent of the animal's total length. They are anatomically complete, and they did project from the body wall (unlike the truly vestigial hind limbs of modern whales), but they could not have made any important contribution to locomotion—the real functional test of intermediacy. Gingerich and his coauthors write: "Hind limbs of *Basilosaurus* appear to have been too small relative to body size to have assisted in swimming, and they could not possibly have supported the body on land." The authors strive bravely to invent some potential function for these minuscule limbs and end up speculating that they may have served as "guides during copulation, which may otherwise have been difficult in a serpentine aquatic mammal." (I regard such guesswork as unnecessary, if not ill-conceived. We need not justify the existence of a structure by inventing some putative Darwinian function. All bodies contain vestigial features of little, if any, utility. Structures of lost usefulness in genealogical transitions do not disappear in an evolutionary overnight.)

Verdict: Terrific and exciting, but no cigar, and no bag-packer for creationists. The limbs, although complete, are too small to work as true intermediates must (if these particular limbs worked at all)—that is, for locomotion on both land and sea. I intend no criticism of *Basilosaurus,* but merely point out that this creature had already crossed the bridge (while retaining a most informative remnant of the other side). We must search for an earlier inhabitant of the bridge itself.

Case Three: Hind limb bones of appropriate size. *Indocetus ramani* is an early whale, found in shallow-water marine deposits of India and Pakistan, and intermediate in age between the *Pakicetus* skull and the *Basilosaurus* hind legs (cases one and two above). In 1993, Gingerich, S. M. Raza, M. Afif, M. Anwar, and X. Zhou reported the discovery of leg bones of substantial size from this species ("Partial Skeletons of *Indocetus ramani* [Mammalia, Cetacea] from the Lower Middle Eocene Domanda Shale in the Sulaiman Range of Punjab [Pakistan]," *Contributions from the Museum of Paleontology of the University of Michigan,* vol. 28, pp. 393–416).

Gingerich and colleagues found pelvic bones, and the ends of both femur and tibia, but no foot bones, and insufficient evidence for reconstructing the full limb and its articulations. The leg bones are large and presumably functional on both land and sea (the tibia, in particular, differs little in size and complexity from that of the related and fully terrestrial mesonychid *Pachyaena ossifraga*). The authors conclude:

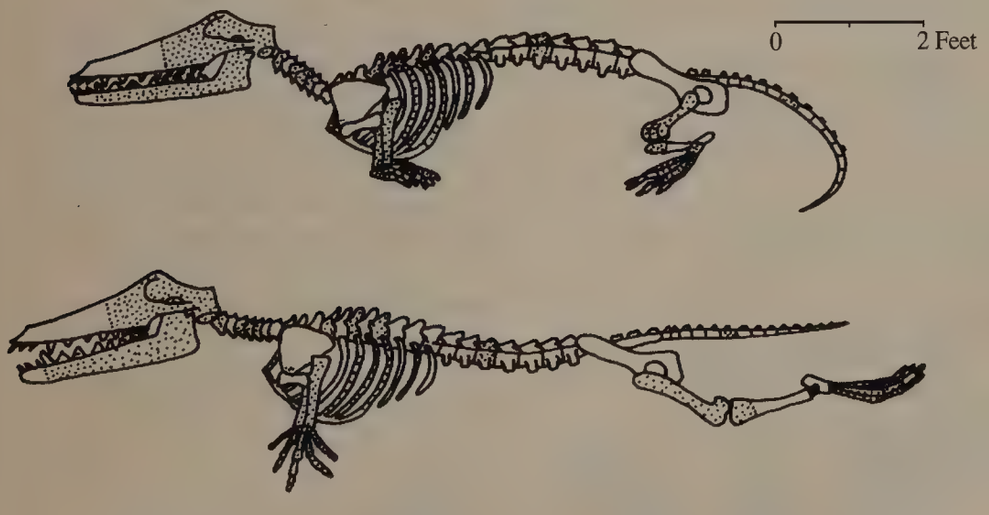
> The pelvis has a large and deep acetabulum [the socket for articulation of the femur, or thighbone], the proximal femur is robust, the tibia is long.... All these features, taken together, indicate the *Indocetus* was probably able to support its weight on land, and it was almost certainly amphibious, as early Eocene *Pakicetus* is interpreted to have been.... We speculate that *Indocetus,* like *Pakicetus,* entered the sea to feed on fish, but returned to land to rest and to birth and raise its young.

Verdict: Almost there, but not quite enough. We need more material. All the right features are now in place—primarily leg bones of sufficient size and complexity—but we need a better sense of connection and function.

Case Four: Large, complete, and functional hind legs for land and sea—finding the smoking gun. The first three cases, all discovered within ten years, surely indicate an increasingly successful paleontological assault upon an old classic problem. Once you know where to look, and once high interest spurs great attention, full satisfaction often follows in short order. I was therefore delighted to read an article by J. G. M. Thewissen, S. T. Hussain, and M. Arif in the January 14, 1994 issue of *Science* ("Fossil Evidence for the Origin of Aquatic Locomotion in Archaeocete Whales," vol. 263, pp. 210–12).

In Pakistan, in sediments almost 400 feet above the beds that yielded *Pakicetus* (and therefore a bit younger in age), Thewissen and colleagues collected a remarkable skeleton of a new whale—not complete, but far better preserved than anything previously found of this age, and with crucial parts in place to illustrate a truly transitional status between land and sea. The chosen name *Ambulocetus natans* (literally, the swimming walking-whale) advertises the excitement of this discovery.

A. natans weighed some 650 pounds, the size of a hefty sea lion. The preserved tail vertebra is elongated, indicating that *Ambulocetus* still retained the long, thin mammalian tail and had not yet trans-



Two reconstructions show Ambulocetus, *a fossil whale from Pakistan, standing, top, and at the end of a swimming stroke, bottom.*
Adapted from *Science,* vol. 263, 14 January 1994

muted this structure to a locomotory blade (as modern whales do in shortening the tail and evolving a prominent horizontal fluke as the animal's major means of propulsion). Unfortunately, no pelvic bones have been found, but most elements of a large, powerful hind leg were recovered—including a complete femur, parts of the tibia and fibula, an astragalus (ankle bone), three metatarsal (foot) bones, and several phalanges. To quote the authors: "The feet are enormous." The fourth metatarsal, for example, is nearly six inches long, and the associated toe almost seven inches in length. Interestingly, the last phalanx of each toe ends in a small hoof, as in terrestrial mesonychid ancestors.

This new bounty of information allows us to infer not only the form of this transitional whale but also, with good confidence, its intermediary style of locomotion and mode of life (an impossibility with the first three cases, for *Pakicetus* is only a skull, *Basilosaurus* had already crossed the bridge, and *Indocetus* is too fragmentary). The forelimbs, smaller than the hind and limited in motion, were "probably used in maneuvering and steering while swimming, as in extant cetaceans ["modern whales" in ordinary language], and they lacked a major propulsive force in water."

Modern whales move through the water by powerful beats of their horizontal tail fluke—a motion made possible by strong undulation of a flexible rear spinal column. *Ambulocetus* had not yet evolved a tail fluke, but the spine had requisite flexibility. Thewissen and colleagues write: "*Ambulocetus* swam by means of dorsoventral [back-to-belly] undulations of its vertebral column, as evidenced by the shape of the lumbar [lower back] vertebra." These undulations then functioned with (and powered) the paddling of *Ambulocetus*'s large feet, which provided the major propulsive force in swimming. Thewissen et al. conclude their article:

> Like modern cetaceans—it swam by moving its spine up and down, but like seals, the main propulsive surface was provided by its feet. As such, *Ambulocetus* represents a critical intermediate between land mammals and marine cetaceans.

Ambulocetus was no ballet dancer on land, but we have no reason to judge this creature as any less efficient than modern sea lions, which do manage, however inelegantly. Forelimbs may have been held out to the sides, largely for stability, with forward motion supplied primarily by extension of the back and consequent flexing of the hind limbs—again, rather like sea lions.

Verdict: Greedy paleontologists, used to working with fragments in reconstructing wholes, always want more (some pelvic bones would be nice, for starters), but if you had given me both a blank piece of paper and a blank check, I could not have drawn you a theoretical intermediate any better or more convincing than *Ambulocetus*. Those dogmatists who by verbal trickery can make white black, and black white, will never be convinced of anything, but *Ambulocetus* is the very animal that they proclaimed impossible in theory.

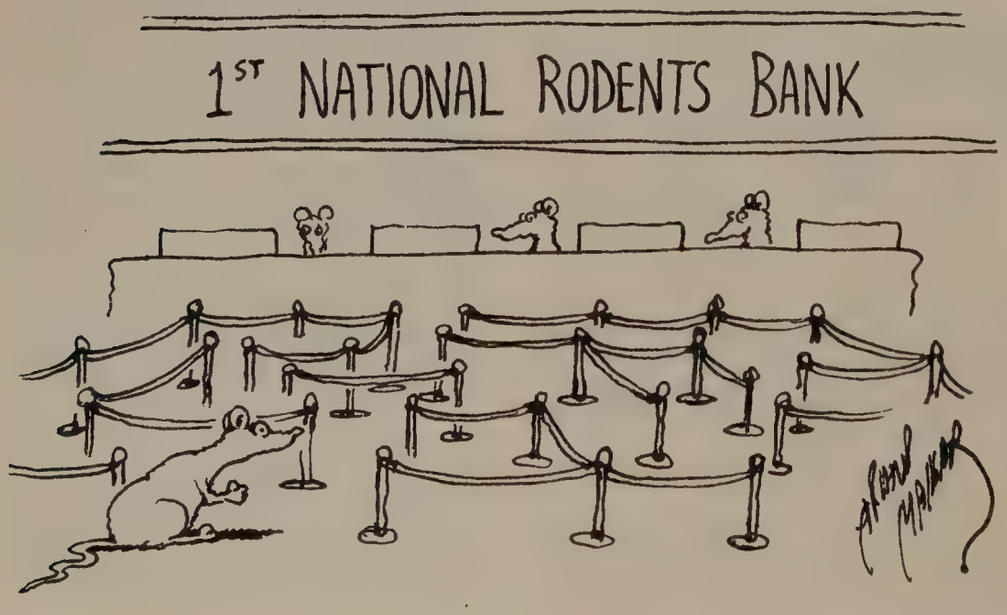
Some discoveries in science are exciting because they revise or reverse previous expectations; others because they affirm with elegance something well suspected, but previously undocumented. Our four-case story, culminating in *Ambulocetus,* falls into this second category. This sequential discovery of picture-perfect intermediacy in the evolution of whales stands as a triumph in the history of paleontology. I cannot imagine a better tale for popular presentation of science or a more satisfying, and intellectually based, political victory over lingering creationist opposition.

Still, I must confess that this part of the tale does not intrigue me most as a scientist and evolutionary biologist. I don't mean to sound jaded or dogmatic, but *Ambulocetus* is so close to our expectation for a transitional form that its discovery could not provide a professional paleontologist with the greatest of all pleasures in science—surprise. As a public illustration, and as a sociopolitical victory, transitional whales may be the story of the decade, but paleontologists didn't doubt their existence or feel that a central theory would collapse if their absence continued. We love to place flesh upon our expectations (or put bones under them, to be more literally correct), but this kind of delight takes second place to the intellectual jolting of surprise.

I therefore find myself far more intrigued by another aspect of *Ambulocetus* that has not received much attention, either in technical or popular reports. For the anatomy of this transitional form illustrates a different and vital principle in evolutionary theory—one rarely discussed or even explicitly formulated, but central to any understanding of nature's fascinating historical complexity.

In our Darwinian traditions, we focus too narrowly on the adaptive nature of organic form, and too little on the quirks and oddities encoded into every animal by history. We are so overwhelmed—as well we should be—by the intricacy in aerodynamic optimality of a bird's wing or by the uncannily precise protective resemblance evolved by certain butterflies that mimic dead leaves. We do not ask often enough why natural selection has honed in upon this *particular* optimum—and not another among a set of unrealized alternatives. In other words, we are dazzled by good design and therefore stop our inquiry too soon when we have answered "how does this work so well?"—when we should also be asking the historian's questions: "why *this* and not *that*?" or "why *this* over here and *that* in a related creature living elsewhere?"

To give the cardinal example from seagoing mammals: the two fully marine orders Sirenia and Cetacea swim by beat-



ing horizontal tail flukes up and down. Since these two orders arose separately from terrestrial ancestors, the horizontal tail fluke evolved twice independently. Many hydrodynamic studies have documented both the mode and the excellence of such underwater locomotion, but they too often stop at an expression of engineering wonder and do not ask the equally intriguing historian's question. Fishes swim in a truly orthogonal manner—also by propulsion from the rear, but with vertical tail flukes that beat from side to side (seals also hold their rear feet vertically and move them from side to side while swimming). The word *orthogonal* is particularly appropriate here—meaning, literally, "at right angles," but also, in technical scientific parlance, "entirely independent."

Both systems work well; both may be "optimal." But why should ancestral fishes favor one system, and returning mammals the orthogonal alternative? We do not wish to throw up our hands and simply say, "six of one, half a dozen of the other; either way will do, and the one chosen is effectively random in any individual case." "Random" is a deep and profound concept of great positive utility and value, but some vernacular meanings amount to pure cop-out, as in this case. It may not matter in the "great scheme of things" whether optimality be achieved vertically or horizontally, but one or the other solution occurs for a reason in any particular case. The reasons may be unique to an individual lineage, and historically bound—that is, not related to any grand concept of pattern or predictability in the overall history of life—but local reasons do exist and should be ascertainable.

This subject, when discussed at all in evolutionary theory, goes by the name of "multiple adaptive peaks." We have some standard examples, but few with any real documentation; most are hypothetical, with no paleontological backup. (For example, my colleague Dick Lewontin loves to present the following case in our joint introductory course in evolutionary biology. Some rhinoceros species have two horns; others one horn. Either result is probably just as good for whatever rhinos do with their horns, and the pathway chosen may not matter. Two and one are equal solutions, or multiple adaptive peaks. He then points out that a reason must exist for two or one in any case, but that the explanation probably resides in happenstances of history, rather than abstract predictions based on universal optimality. So far so good. History's quirkiness, by its role in populating the earth with a variety of unpredictable, but sensible and well-working, anatomical designs does constitute the main fascination of this theme in evolution theory. But we can go no further with rhinos, for we have no data for understanding the particular pathway chosen in any case.)

I love the story of *Ambulocetus* because it has provided hard data on reasons for a chosen pathway in a classical case of multiple adaptive peaks. Why did both orders of fully marine mammals choose the orthogonal solution of horizontal tail flukes? Previous discussions have made the plausible argument that definite legacies of terrestrial mammalian ancestry established the anatomical predisposition. In particular, many mammals (but not other terrestrial vertebrates), especially among agile and fast-moving carnivores, run by flexing the spinal column up and down (conjure up a sprinting tiger in your mind, and picture the undulation of the back). Mammals that are not particularly comfortable in water—dogs dog-paddling for instance—may keep their backs rigid and move only by flailing their legs. But semiaquatic mammals that swim for a living—notably the river otter (*Lutra*) and the sea otter (*Enhydra*)—move in water by powerful vertical bending of the spinal column in the rear part of the body. This vertical bending propels the body forward both by itself (and by driving the tail up and down) and by sweeping the hind limbs back and forth in paddling as the body undulates.

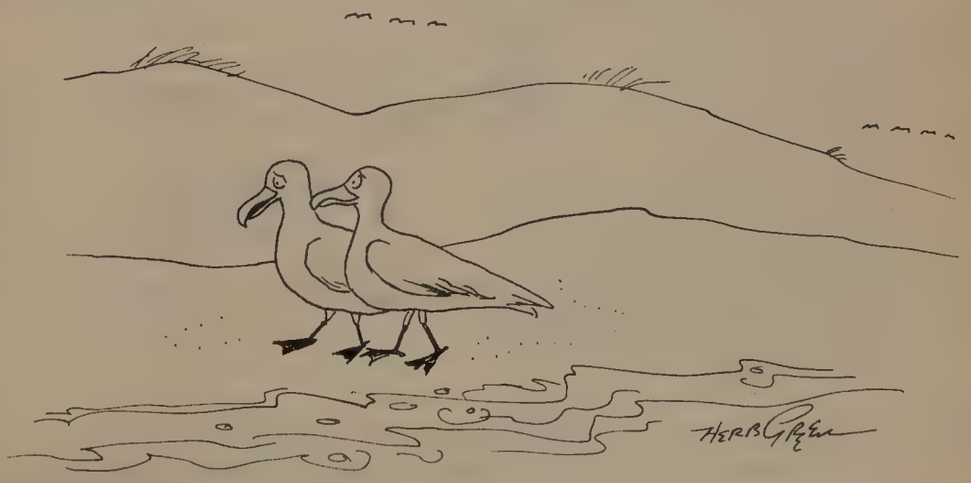
Thus, horizontal tail flukes may evolve in fully marine mammals because inherited spinal flexibility for movement up and down (rather than side to side) directed this pathway from a terrestrial past. This scenario has only been a good story up to now, with limited symbolic support from living otters, but no direct evidence from the ancestry of whales or sirenians. *Ambulocetus* provides this direct evidence in an elegant manner—for all pieces of the puzzle lie within its recovered skeleton.

We may infer from a tail vertebra that *Ambulocetus* retained a long and thin mammalian tail, and had not yet evolved the horizontal fluke. We know from the spinal column that this transitional whale retained its mammalian signature of flexibility for up-and-down movement—and from the large hind legs that undulation of the back must have propelled the powerful, paddling feet, as in modern otters.

Thewissen and colleagues draw the proper evolutionary conclusion from these facts, thus supplying beautiful evidence to nail down a classical case of multiple peaks with paleontological data: "*Ambulocetus* shows that spinal undulation evolved before the tail fluke.... Cetaceans have gone through a stage that combined hind limb paddling and spinal undulation, resembling the aquatic locomotion of fast swimming otters." The horizontal tail fluke, in other words, evolved because whales carried their terrestrial system of spinal motion to the water.

History channels a pathway among numerous theoretical alternatives. In his last play, Shakespeare noted that "what's past is prologue; what to come, in yours and my discharge." But present moments build no such wall of separation between a past that molds us and a future under our control. The hand of the past reaches forward right through us and into an uncertain future that we cannot fully specify. History has you and me, brother and sister—the whole world—in her hands.

Stephen Jay Gould teaches biology, geology, and the history of science at Harvard University.



"I guess the hardest thing for me growing up was when I realized I wasn't going to be an eagle."

Spacious Skies and Tilted Axes

Why were plants domesticated so early in the Fertile Crescent? And why did those crops then spread so far and so fast?

by Jared Diamond

On the map of the world, compare the shapes and orientations of the continents. You'll immediately be struck by an obvious difference. The Americas span a much greater distance north to south (9,000 miles) than east to west (only 3,000 miles at the widest, narrowing to a mere 40 miles at the Isthmus of Panama). That is, the major axis of the Americas is north–south. That's also true, although to a lesser degree, for Africa. In contrast, the major axis of Eurasia is east–west. What effect, if any, did those different orientations of the continents' axes have on human history?

Merely posing this question may raise some people's hackles. It seems to invite the label "environmental determinism"—a concept that is sometimes lampooned as implying that human creativity counts for nothing, and that climate irresistibly programs us like computers. Naturally, geographic interpretations can be wrong or carried to an extreme. But denying that geography influences the broad course of history is equally extreme.

Human societies have evolved at different average rates on different continents for at least the past ten thousand years. Specifically, developments such as agriculture, metallurgy, writing, and empires arose earliest in parts of Eurasia, arose later in the Americas and sub-Saharan Africa, and did not arise indigenously in Australia. Such persistent patterns can hardly be dismissed as accidents reflecting where a few geniuses happened to be born. Bigots prefer to invoke supposed differences in I.Q. among populations, but have conspicuously failed to demonstrate such differences. Instead, these broadest patterns of history seem likely to have arisen from influences of differing geographic factors. I believe that the enormous, sometimes tragic, consequences of those differences in the continents' axes contributed greatly to the very different treatment that history has meted out to Native Americans, Africans, and Eurasians in the last 500 years.

My interest in this question has been restimulated by a recently published, revised edition of a wonderful book, *Domestication of Plants in the Old World,* by Israeli geneticist Daniel Zohary and German botanist Maria Hopf. The book concerns the early importance of that part of Southwest Asia variously known as the Fertile Crescent, or the Near East. This area was the earliest site for a whole string of developments, including towns, writing, empires, and what we term (for better or worse) *civilization.* All those developments sprang, in turn, from the advent of dense human populations and the rise of food production—in the form of agriculture and animal husbandry—that made it possible to store food surpluses and feed nonfarming specialists.

Since food production was the first of the major innovations that arose in the Fertile Crescent, anyone attempting to understand the broad pattern of human history must begin by trying to understand why domestication started so early there. Why, too, did it spread from there so fast and so far? Zohary and Hopf are illuminating on both points.

The early start in the Fertile Crescent, according to Zohary and Hopf, was due to a combination of geographic, climatic, and biotic factors. Western Eurasia (Europe plus Southwest Asia) includes the world's largest zone of so-called Mediter-

THE WORLD'S FIVE REGIONS WITH MEDITERRANEAN CLIMATE

Mediterranean climate—mild, wet winters and hot, dry summers—favored the evolution of big-seeded, annual plants. Such plant species, including the wild ancestors of barley and wheat, were especially abundant in the Fertile Crescent (light green). Arrows indicate the major axes of continents.

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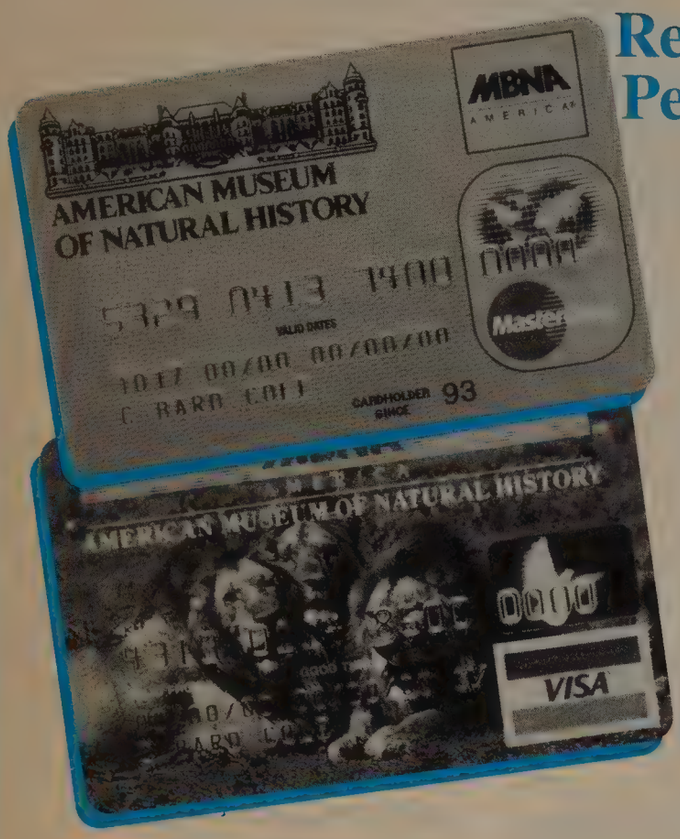

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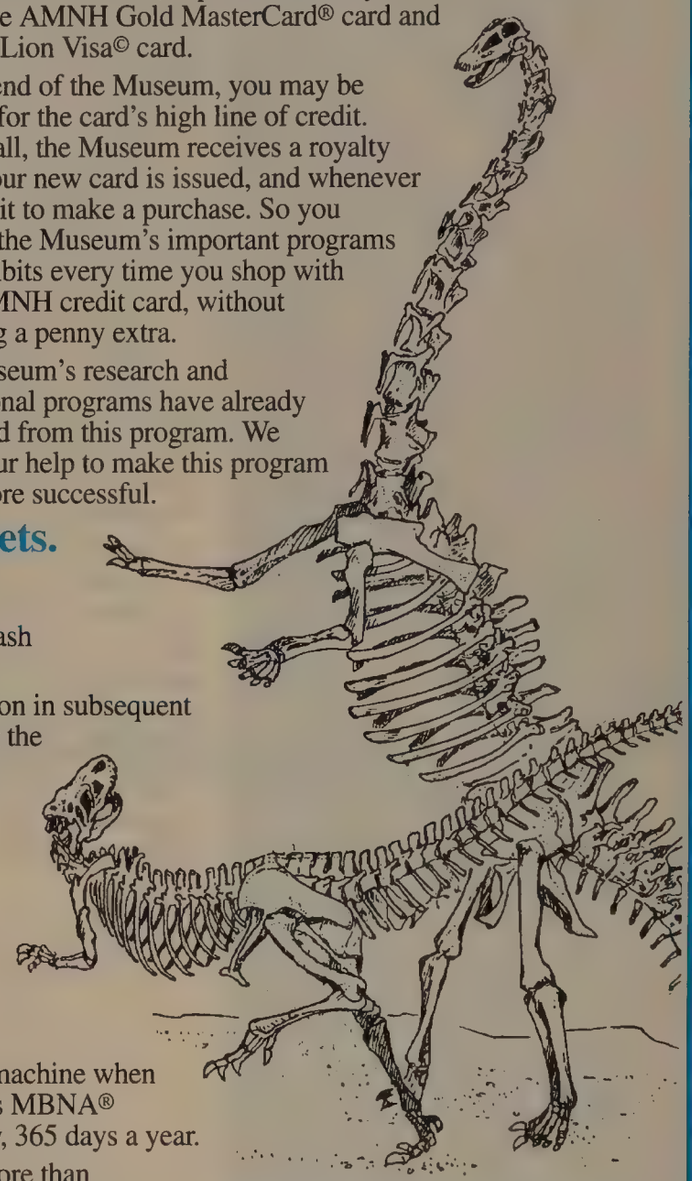

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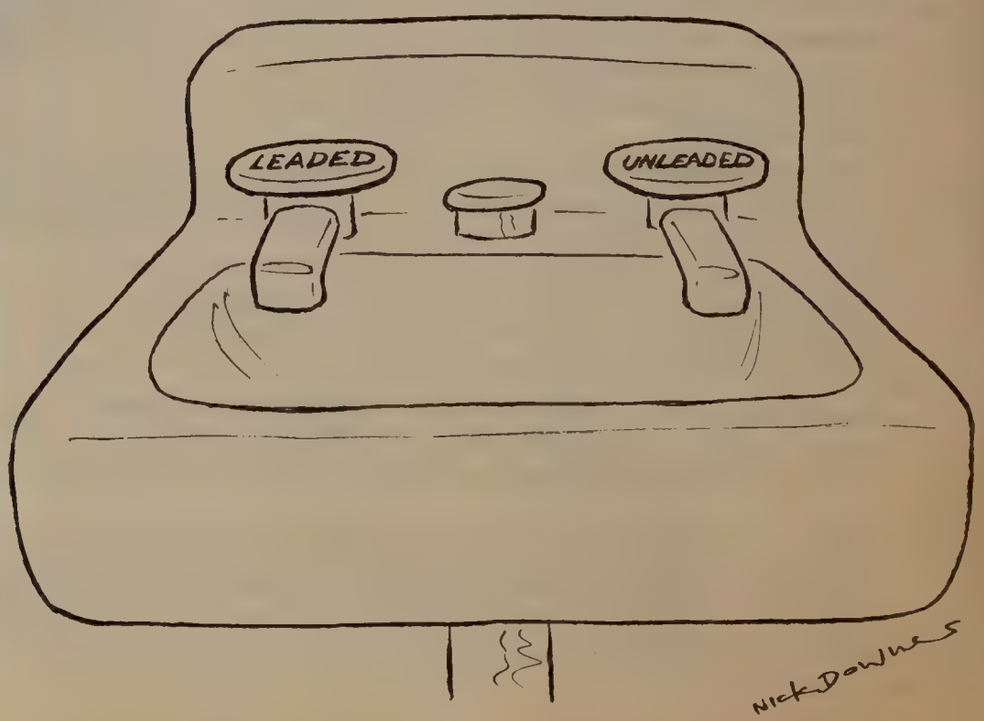
ranean climate, characterized by mild, wet winters and hot, dry summers. The world's other Mediterranean zones are the Cape of South Africa, the central coast of Chile, parts of southern Australia, and my homeland of coastal California. Among those Mediterranean zones, western Eurasia's is not only the largest but may also experience the greatest climatic variation between seasons and years. That climate favored the evolution of annual plants that survived the long, dry summer by putting much of their energy into big, edible seeds, while leaving the inedible remainder of the plant to die back and regrow each year. Because of the Fertile Crescent's extreme Mediterranean climate, its plants provided hungry humans with an exceptionally high percentage of annuals.

The region also has a high percentage of hermaphroditic, predominantly self-pollinating annuals—that is, ones that usually pollinate themselves but are occasionally cross-pollinated. As Zohary and Hopf explain, that feature was also good for the first farmers. Occasional cross-pollination generated several strains to choose from, while the predominant self-pollination insured that varieties selected as superior usually perpetuated themselves unchanged and were not immediately lost by hybridization with less desirable strains.

Some of those big-seeded, self-pollinating annuals, such as the wild ancestors of barley and wheats, were so abundant as wild stands in the Fertile Crescent that they were already being collected by hunter-gatherers before the emergence of farming. Eventually, people began to increase their yields of those wild plants by tilling soil, intentionally sowing seeds, harvesting, and threshing. That new system unintentionally transformed the wild plants into cultivated varieties because people naturally preferred to sow, grow, eat, and resow seeds of those particular plant varieties with desirable features. Depending on the plant species, those features might include larger seeds, a less bitter taste, more uniform germination, and seeds that remain on the parent plant.

The Fertile Crescent also offered other advantages to incipient farmers. Its range of elevations, from the lowest spot on earth (the Dead Sea) to mountains nearly 17,000 feet high, meant that within a short distance there was a corresponding range of environments, hence a great diversity of wild plants available for potential domestication. These varied environments also harbored many species of large wild mammals, some of which were the ancestors of our most important domesticated mammals today. Southwest Asia's few large rivers and short coastline provided scant aquatic resources to make the hunter-gatherer life style competitive with incipient farming. Climatic changes about ten thousand years ago at the end of the Pleistocene—changes that exterminated some large mammal species and expanded habitats rich in annual plants ancestral to crops—quickly tipped the balance from hunting and gathering to domestication.

By about 8000 B.C., the peoples of the Fertile Crescent were domesticating numerous valuable plants. Most of the calories consumed by those first farmers came from high-carbohydrate cereals such as wheat and barley, the most useful of the dozens of wild cereal species in the area by virtue of their large seeds, abundance,



and annual growth. Unlike protein-poor corn and rice, which became the leading cereals of the Americas and eastern Asia respectively, the wheats of the Fertile Crescent had a substantial protein content of 8 to 14 percent.

During or soon after the onset of farming in Mesopotamia, these starchy cereals were complemented by two types of food with an even higher protein content: legumes, especially peas and lentils, which have 20 to 25 percent protein, and domestic animals (sheep, goats, cattle, and pigs). The animals yielded wool and leather as well. One other crop, flax, not only filled out the dietary trinity of carbohydrate, protein, and fat with its very oily seeds but also provided the oldest cultivated source of plant fiber for making clothes. Linen from flax reigned supreme as Europe's preferred plant textile material until it was finally replaced by cotton and synthetics during and after the Industrial Revolution. Thus, the Fertile Crescent's first farmers assembled a balanced package for intensive food production, based on eight main crops and four animals that filled humanity's basic economic needs: carbohydrate, protein, fat, clothing, and, eventually, milk products and animal transport.

Soon after food production arose in the Fertile Crescent, it radiated into other parts of western Eurasia and North Africa, spreading progressively farther west and east. In a striking map, Zohary and Hopf illustrate how agriculture reached Greece and Cyprus by 7000 B.C., Egypt and India soon after 6000 B.C., central Europe by 5400 B.C., and Britain about 4000 B.C. (These are so-called calibrated radiocarbon dates—dates based on the regular decay of the radioactive isotope carbon-14 and corrected for slight fluctuations in atmospheric isotope with time.) Food production in the new areas was launched by the crucial package of the same domesticated plant and animal species that launched it in the Fertile Crescent.

Of course, not ali pieces of the package spread to all those outlying areas: for example, Egypt was too warm for einkorn wheat to become established. Some inhabitants of outlying areas went on to domesticate a few local crops of their own, such as poppies in western Europe. But most food production in these regions depended at first on the same group of Fertile Crescent domesticates. Their spread was soon followed by the spread of other innovations originating in or near Mesopotamia, including the wheel, writing, metalwork-

ing techniques, milking, fruit trees, and beer and wine production.

Why did the same plant package launch food production throughout western Eurasia? Was the same set of wild plants found useful in many areas and independently domesticated? No, that's not the case. Many of the Fertile Crescent's "founder crops" (to use Zohary's and Hopf's term) don't even occur in the wild outside Southwest Asia. In Egypt, for instance, of the eight main founder crops, only barley grows wild. Egypt's Nile Valley provides an environment similar to that of the Tigris and Euphrates Valley, so the package that worked well in Mesopotamia also worked well enough in the Nile Valley to trigger the spectacular rise of indigenous Egyptian civilization. The Sphinx and the pyramids, then, were built by people fed on crops originating in the Fertile Crescent, not in Egypt.

Wild ancestors of crops that were first domesticated in Southwest Asia also existed in Europe, Asia, and India, but we can be confident that the crops first produced there were mostly obtained from Southwest Asia and were not local domesticates. All modern cultivated varieties of most of the Fertile Crescent's founding crops either share only one arrangement of chromosomes out of multiple arrangements found in the wild ancestor, or else they share only a single mutation (out of many possible mutations) by which the cultivated varieties differ from the wild ancestor in characteristics desirable to humans. For instance, all cultivated peas share the same recessive gene that prevents ripe pods from spontaneously popping open and spilling their peas, as wild pea pods do. Evidently, most of the Fertile Crescent's founder crops were never domesticated again elsewhere after their initial domestication. Had they been repeatedly domesticated independently, they would exhibit legacies of those multiple origins in the form of varied chromosomal arrangements or varied mutations.

The ancestors of most of the founder crops have multiple wild relatives, in the Fertile Crescent and elsewhere, that would also have been suitable for domestication.

For example, peas belong to the genus *Pisum,* which consists of two wild species: *P. sativum,* the one that became domesticated to yield our garden peas, and the common and widespread *P. fulvum,* which was never domesticated. Yet the latter taste good, either fresh or dried. Similarly, domesticated wheat, barley, lentils, chickpeas, beans, and flax all have numerous wild relatives. Some of those related beans and barleys were indeed domesticated independently in the Americas or China, but in the Near East only one of several potentially useful wild species of a given plant was domesticated—probably because it spread so quickly that people soon stopped gathering the other wild relatives and ate only the crop. As Zohary and Hopf emphasize, the crop's rapid spread preempted any possible further attempts to domesticate its relatives or to redomesticate its ancestor.

Why was the spread of crops from the Fertile Crescent so rapid? The answer has to do with that east–west axis of Eurasia. Localities east and west of one another at the same latitude share exactly the same seasonal variations in day length. To a lesser extent, they also tend to share similar diseases, temperature, and rainfall. For example, southern Italy, northern Iran, and Japan, all located at about the same latitude but lying thousands of miles apart, are more similar to one another in climate than each is to a location lying a mere 1,000 miles due south. And the germination, growth, and disease resistance of plants there are adapted to precisely those features of climate. As a consequence, most of the Fertile Crescent crops grow well in southern Europe and Japan, but grow poorly at the equator.

In other words, Fertile Crescent domesticates spread west and east so rapidly because they were already well adapted to the climates of the regions to which they were spreading. Once farming crossed from the plains of Hungary into central Europe about 5400 B.C., it spread so quickly that the sites of the first farmers in the vast areas from Poland west to Holland (marked by their characteristic pottery with linear decorations) were nearly contemporary. By the time of Christ, cereals of Fertile Crescent origin were growing over the 10,000-mile expanse from the Atlantic coast of Ireland to the Pacific coast of Japan. That west–east expanse of Eurasia is the largest land distance on earth.

Thus, Eurasia's west–east axis allowed Fertile Crecent agriculture to spread over the band of temperate latitudes from Ireland to the Indus Valley and to enrich the agriculture that arose independently in eastern Asia. Conversely, Eurasian crops that were first domesticated far from the Fertile Crescent but at the same latitudes were able to spread back to the Near East. Today, when seeds are transported over the whole globe by ship and plane, we take for granted that our meals are a geographic mishmash. A typical American fast-food restaurant meal would include chicken (first domesticated in Southeast Asia) and potatoes (from the Andes) or corn (from Mexico), seasoned with pepper (from India), and washed down with a cup of coffee (of Ethiopian origin). But 2,000 years ago, Romans were already nourishing themselves with a range of foods that Zohary and Hopf show to have mostly originated elsewhere. Of Roman crops, only oats and poppies were native to Italy. Roman staples were still the Fertile Crescent founder package, supplemented by quince (originating from the Caucasus); millet and cumin (domesticated in central Asia); cucumber, sesame, and citrus fruit (from India); and chicken, rice, apricots, peaches, and foxtail millet (originally from China).

Contrast this easy east–west diffusion in Eurasia with the difficulties of diffusion

along Africa's north–south axis. Most of the Fertile Crescent founder crops reached Egypt very quickly and then spread as far south as the cool highlands of Ethiopia, beyond which they spread no farther. South Africa's Mediterranean climate would have been ideal for them, but the 2,000 miles of tropical conditions between Ethiopia and South Africa posed an insuperable barrier. Instead, African agriculture south of the Sahara was launched by the domestication of such wild plants as sorghum and African yams, which are indigenous to the Sahel and tropical West Africa and are adapted to the warmth, summer rains, and relatively constant day-lengths of those low latitudes.

Similarly, the southward spread of Fertile Crescent domestic animals through Africa was stopped or slowed by climate and disease, especially by trypanosome diseases carried by tsetse flies. The horse never made it farther south than West Africa's kingdoms north of the equator. Cattle remained stuck for 2,000 years at the northern edge of the Serengeti Plain, while new types of human economies and livestock breeds were being developed. Not until about the time of Christ, some 7,000 years after they were domesticated in the Fertile Crescent, did they finally straggle into South Africa along with sheep and goats. Tropical African crops had their own difficulties spreading south in Africa, reaching South Africa with black African farmers (the Bantu) just after the arrival of those Fertile Crescent livestock. However, those tropical African crops were never able to go beyond South Africa's Fish River, stopped by Mediterranean conditions to which they were not adapted.

Because of this, South Africa's indigenous Khoisan peoples (otherwise known as Hottentots and Bushmen) acquired livestock but remained without agriculture. They became outnumbered and were replaced northeast of the Fish River by black African farmers, whose southward spread halted there. Only when European settlers arrived by sea in 1652, bringing with them their Fertile Crescent crop package, did agriculture thrive in South Africa's Mediterranean zone. The collisions of all those elements produced the tragedies of modern South Africa: the quick decimation of the Khoisan by European germs and guns; a century of wars between Europeans and blacks; another century of racial oppression; and now, efforts by Europeans and blacks to seek a new mode of coexistence in the former Khoisan lands.

Contrast also the ease of east–west diffusion in Eurasia with the difficulties of diffusion along the Americas' north–south axis. The cool highlands of Mexico would have provided ideal conditions for raising llamas, guinea pigs, and potatoes, all domesticated in the cool highlands of South America. But the northward spread of those Andean species was stopped completely by the hot intervening lowlands of Central America. As a result, the Olmec, Maya, Aztec, and all other native civilizations of Mexico remained without pack animals and without any edible domesticated mammals except for dogs.

Similarly, domesticated turkeys or sunflowers of North America might have thrived in the Andes, but their southward spread was also stopped at the tropics. For thousands of years after corn was domesticated in Mexico, it was unable to spread farther north because of the relatively cool climates and shorter growing season. About the time of Christ, corn finally took root in what is now the eastern United States, but initially only as a very minor crop. Not until A.D. 800, when a hardy variety of corn adapted to northern climates was developed, did this grain finally trigger the flowering of the most complex Native American society of North America, the Mississippian culture—just in time for it to be decimated by European-introduced germs.

In contrast to the single Fertile Crescent origin that Zohary and Hopf trace for most widespread Eurasian crops, many apparently widespread Native American crops prove, on closer examination, to consist of distinct varieties or related species, independently domesticated in Mesoamerica and South America. That's true, for example, of American cotton, beans, lima beans, chili peppers, and squashes. While Fertile Crescent crops spread rapidly and preempted other incipient developments of domestication, slow diffusion and many independent domestications were the rule in the Americas.

Slower development of Native American agriculture (compared with Old World agriculture) contributed to the slower development of Native American writing, metallurgy, technology, shipping, and empires. Those differences helped seal the outcome of the collision between Native Americans and European settlers that began with Columbus. Yes, I acknowledge other geographic and biological contributing factors as well. Humans colonized Eurasia long before they colonized the Americas. In addition, the Americas had few domesticable large wild animal species, while in Europe many such animals were used to pull plows or make cavalry charges. Those domesticates harbored the animal pathogens from which Eurasia's most lethal weapon, human pathogens such as the smallpox and measles viruses, evolved. But the different orientations of the continents' axes remain an immensely important factor.

In the United States, the patriotic song "America the Beautiful" invokes our spacious skies, our amber waves of grain. Alas, that song reverses geographic realities. No waves of native grain ever reached the Pacific coast of North America, just as none ever stretched from Egypt to South Africa, while amber waves of wheat and barley did come to stretch across the spacious skies of Eurasia. These differences don't prove that widely distributed crops are admirable, nor do they testify to the superior ingenuity of early Eurasian farmers. They reflect instead the orientation of Eurasia's axis compared with that of the Americas or of Africa. Around those axes turned the fortunes of history.

Jared Diamond is a physiologist and evolutionary biologist at the University of California Medical School, Los Angeles.

Life Styles of the Rich and Famou

Beauty meets the Beast

by Roger L. Welsch

I was on tour last fall, peddling my latest book, and was about to appear on a talk show on a Kansas City television station. The producer led me to the studio's "green room," the dressing room where guests brace themselves. I got the distinct feeling that I'd been there before—not *déjà vu,* or *presque vu,* but *vraiment vu.*

"Yes," the producer said to my wonderment. "You were here four years ago to talk about another book."

"Y-e-e-s," I said, the memory becoming clearer. "I shared this dressing room with some tall, sort of attractive young woman who had just appeared on the cover of some fashion magazine or another, right?"

"*Some* tall, *sort of* attractive young woman," the producer sputtered. "That was Cindy Crawford!"

Good grief. I shared a dressing room with Cindy Crawford, one of the most beautiful women in the world. I should have given her a copy of my book. I should have gotten her autograph on her magazine cover. I should have had her scratch her initials on my forehead with a piece of broken glass.

Weeks later, when I told all my buddies this story up at Slick's Tavern, they expressed so much doubt and ridicule (not that I had shared the room with Ms. Crawford, but that I had not taken advantage of the occasion, having instead *forgotten* it), that in order to restore my male credentials I found myself also remembering that as I left the dressing room, Cindy said huskily, "Hey, you in the overalls—nice keister." (Although, now that I think of it and as I have made clear to Lovely Linda, she might actually have said, "Nice to meet you, sir.")

The point is—and I suppose you are wondering by now what the point is—beauty is not something immediately and inherently evident to all observers. In the case of Ms. Crawford, she was to my eye simply a nice-looking young woman until I was instructed by magazines, newspapers, comedians, television, calendars, and male friends that she is a ravishing beauty. Of course, Cindy might have been having a particularly bad day or I might have been preoccupied with my own coif, but the fact remains, physical beauty is cultural, not natural. What is considered beautiful in one culture or era is not necessarily beautiful in another.

If there is a universal rule of beauty, it is that we consider those physical characteristics that reflect wealth to be beautiful. In classic English ballads, which exemplify medieval and Renaissance times and customs, a good deal of plot development revolves around the tensions between characters like "fair Eleanor" and "the nut-brown maiden." Fair Eleanor is attractive, by virtue of her being fair, while the nut-brown maiden—well, you know, as we used to say in college, "She plays the piano and all the girls like her." If you were poor, you had to work, and work was almost inevitably outside. If you were rich, you sat around the castle all day, never venturing into the glare of the sun and dangers of the countryside. Pale skin therefore reflected wealth and came to represent beauty.

So English women went to extremes to have translucently white skin. They carried parasols, swaddled their arms, shaded their faces, and powdered and bleached their skins, right on up to fairly recent times. But these days working women are indoors—sitting behind desks in corporate offices, standing before classrooms, diagnosing patients, checking out books, taking care of kids. On the other hand, the idle rich are outdoors—playing tennis, skiing, and traveling to sunnier climes. Today, the nut-brown English maiden is the wealthy one, and therefore desirable, and the only resort for pasty Fair Eleanor is a tanning salon.

Same with men. Fabio? Marky Mark? Schwarzenegger? Obviously, these guys have enough money to spend their lives lounging around beaches, working out in salons, building their pecs, shaving their chests. Working lugs get their exercise pounding on computer keyboards, checking mortality tables, taking motivation workshops.

In societies where famine is a constant threat, fat is a sign of wealth and, ergo, beautiful. That has historically been true even of European and American culture. Until recently. Now, when plenty is the rule rather than the exception, fat is easy to come by. Fat is no longer a sign of wealth. Just ask me.

These days, models like Kate Moss declare through their physiques (or nonphysiques), "Me worry about famine? You must be kidding." Wow, our greedy little psyches gush: "She's absolutely *skeletal.* She must be stinking rich and is therefore ravishingly beautiful."

Body mutilation, from tattooing to extreme manicure, requires time to achieve and is visible evidence of extended leisure and undemanding physical exertion. Elaborate coiffures—shaved patterns or cornrows—take time, money, and the expensive attention of others. Same with ornate costuming, from lip rings and neckties to high heels and body paint. Squandered energy, self-imposed physical restriction, idle time, and, even better, the consumption of other people's time require and indicate wealth and have come to represent beauty.

The thesis extends beyond human body presentation, of course. The less arable a piece of land is, the more scenic it becomes. So tourists speed past acres of corn and wheat, bored to tears, to gasp at the sterile emptiness of the Grand Canyon or Disneyland. The evident utility of the station wagon makes it hopelessly drab while the total inefficiency of a Lamborghini makes it the stuff of dreams.

But you don't want to know what has determined beauty in the past. You want to be a step ahead for the future, right? What

will constitute wealth and therefore symbolize beauty tomorrow? Not voting or owning a firearm, for one thing. These days there's no rich like *felon* rich, so a sure sign of wealth is a solid prison record and all the nonperks of conviction. The only way you can afford a million-dollar fine, after all, is to steal ten million.

Similarly, a sure sign of wealth is spending $6 million being elected to a political job that pays only $213 a month. Everyone knows that if it costs that much to get there, something's going on to make it well worth the bucks.

I'm not as certain about marital records as wealth indicators: will those who have never loved and lost be seen as wealthy, or those who have loved and could afford to lose? A nice combination would be a felon entitled to conjugal visits.

And to my knowledge, only a handful of people left in America can survive financially without having written a book, so a limited bibliography will, I predict, soon be accepted as important evidence of beauty: "I have so much money, I didn't need to reveal how my parents mistreated me when I was a kid."

The most remarkable direction for the future, however, will be homeliness. Beauty has become such an issue in America today, such a factor in social and financial success, that the real extravagance of the future will be being ugly. Anyone wealthy enough not to care about being attractive will be viewed as attractive for that very reason. I know this sounds pretty convoluted, but take a look at the latest fashion magazines. I think I may even be late in my prediction. Homely is in vogue, pretty is passé.

Sorry, Cindy. Looks like you're out and I'm in! By this time next year you'll be telling your boss down at the laundry how *you* once shared a dressing room with *me*.

Folklorist Roger L. Welsch lives on a tree farm in Dannebrog, Nebraska.

Tales from a Peruvian Crypt

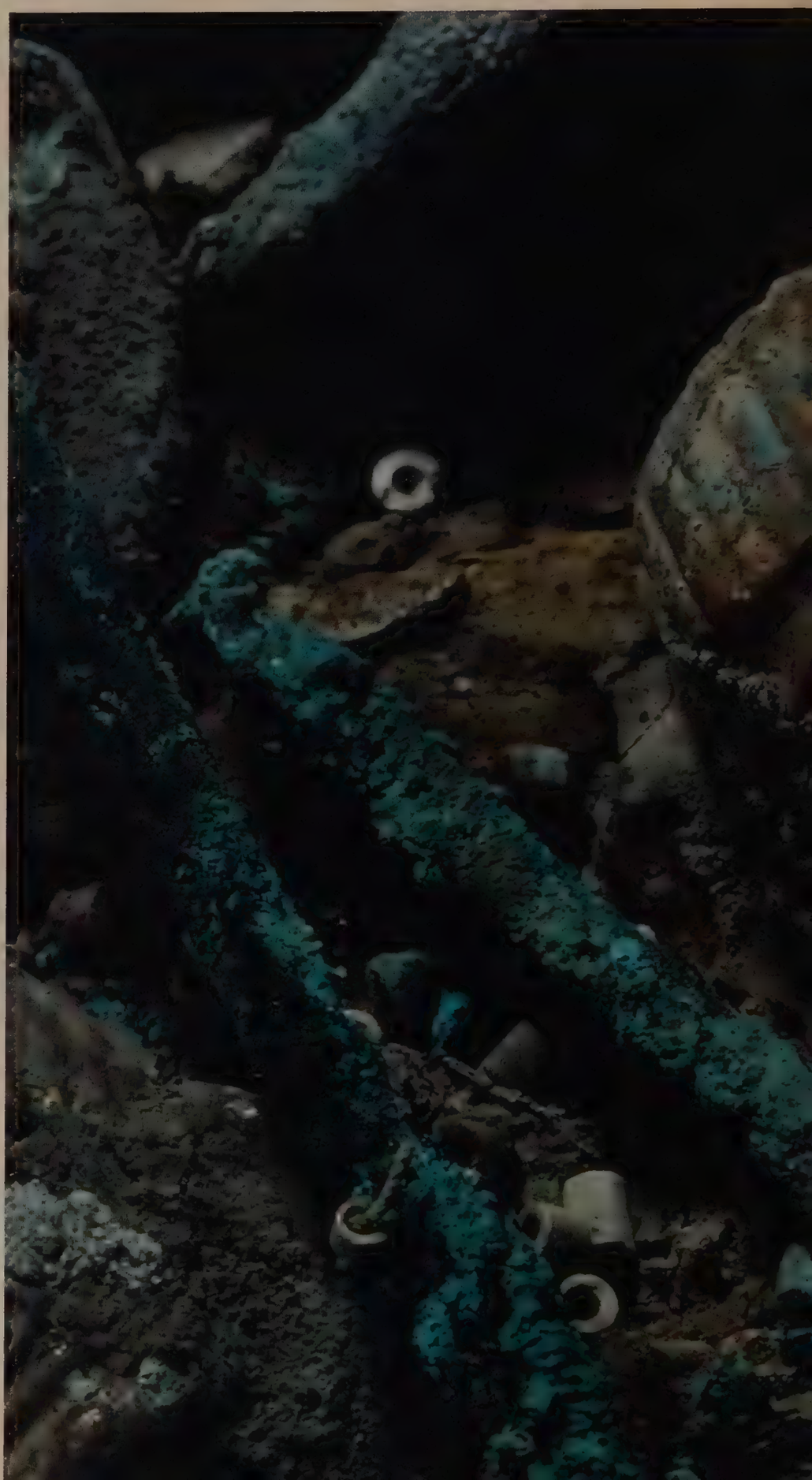
The looting of a prehistoric pyramid stimulates an operation in salvage archeology, with unexpected scientific dividends

by Walter Alva and Christopher B. Donnan

In the fertile river valleys that relieve Peru's arid coastal plain, mud-brick pyramids stand as the most visible evidence of the prehistoric Moche civilization, which flourished between the first and eighth centuries A.D. Rising out of agricultural fields in the Moche River valley, the massive Pyramid of the Sun was the largest structure ever built in South America. With a ramp that led up to small buildings on its flat summit, it stood about 135 feet high and sprawled over 12.5 acres at its base. It once contained more than 130 million sun-dried bricks. Some of it has eroded away naturally, while part was demolished in the seventeenth century by Spanish entrepreneurs in search of rich burials or other treasures.

About ninety-five miles north of the Pyramid of the Sun, in the Lambayeque River valley, the Moche cemeteries and three pyramids near the village of Sipán have long been the target of looters. Over the years they have dug many deep holes with picks and shovels in hopes of locating intact tombs containing ceramic vessels, shell and stone beads, and rarer ornaments of silver and gold. By November of 1986, they had nearly exhausted the cemeteries, and one group of treasure seekers decided to focus on the smallest pyramid. Working at night to avoid police detection, they dug a series of holes, but found little of value. Then, on the night of February 16, 1987, at a depth of about twenty-three feet, they suddenly broke into one of the richest funerary chambers ever looted, the tomb of an ancient Moche ruler.

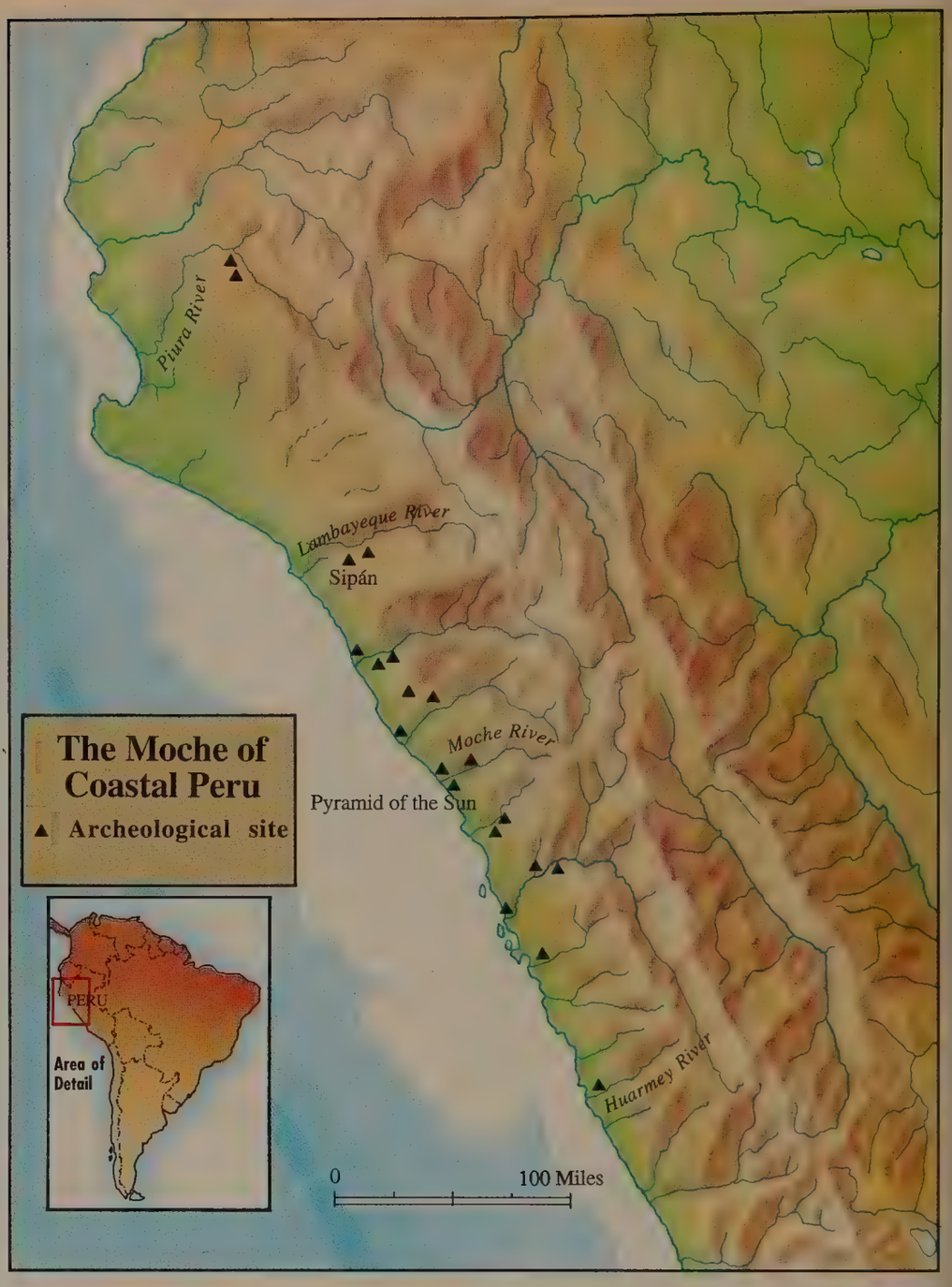
The looters removed several sacks of gold, silver, and gilded copper artifacts. They also took some ceramic vessels, but they broke and scattered many others in their haste. Almost immediately, the looters quarreled over the division of the spoils, and one of them tipped off the police. The authorities were able to seize some of the plundered artifacts, but only a pitiful amount was salvaged from the find. The rest disappeared into the hands of Pe-



Adapted from *Royal Tombs of Sipán,* by Walter Alva and Christopher B. Donnan (Los Angeles: Fowler Museum of Cultural History, University of California, 1993).

A two-inch, hollow gold head, one of ten matching beads that formed a necklace, was part of the finery buried with a Moche lord about A.D. *150. The find came from the third intact tomb excavated by archeologists at Sipán.*

Joe LeMonnier



ruvian collectors or was illegally exported for sale in Europe, Japan, and the United States.

Building on civilizations that preceded them in coastal Peru, the Moche developed their own elaborate society, based on the cultivation of such crops as corn and beans, the harvesting of fish and shellfish, and the exploitation of other wild and domestic resources. They had a dense, socially stratified population, with large numbers of workers devoted to the construction and maintenance of irrigation canals, pyramids, palaces, and temples. Their lords apparently received food and commodities from their subjects and distributed them to lesser nobles and to the potters, weavers, metalworkers, and other artisans who created luxury objects for the elite. In sculptures, decorated ceramics, and murals, archeologists have glimpsed many complex scenes of Moche life, including hunting, combat, and ceremonial practices.

The luxury items from Sipán that were confiscated by the police, including hollow gold beads of various shapes and sizes, hinted at the magnificence of the plundered burial, which must have belonged to one of the Moche elite. More fortune-hunters descended on the site in search of overlooked valuables. They hacked at the tomb walls and sifted through the excavated dirt. By the time the police secured the area, little was left except a boot-shaped hole. Nevertheless, with armed guards stationed around the clock, we hastily organized an archeological survey to learn everything possible of scientific value (author Walter Alva directed the project; coauthor Chistopher B. Donnan was one of the many participants).

We began by making a contour map of the three pyramids and what remained of their ramps and adjacent plazas. The small pyramid, where the tomb had been found, was riddled with looters' tunnels, but in some places, the piles of dirt they had excavated helped preserve the original contours. The tunnels also enabled us to examine the internal construction. The pyramid and the rest of the complex evidently had been built and rebuilt over a long period of time, undergoing many changes as the various parts were enlarged. The small pyramid seems to have gone through six phases, beginning in the first century A.D. and ending about 300.

Although the burial chamber had been gouged out of shape, we were able to determine that it had originally been roofed with large wood beams, which had decomposed. To our great surprise, we were able to uncover some of the tomb's contents that had been missed by the original looters and the subsequent gleaners. Clearing along one side of the chamber, we found the remains of a large, gilded copper crown decorated with metal disks; four ceramic jars modeled in the shape of human figures; and a copper mask with inlaid turquoise eyes. In excavating these, we also discovered a heavy copper scepter forty inches long, pointed at one end and bearing a three-dimensional architectural model on the other. The model depicted a platform with a balustrade, surrounding an open-front building with one back wall and a peaked roof supported by posts. Seventeen double-faced human heads decorated the roof ridge, while depicted in relief on the wall was a supernatural creature, half feline and half reptile, copulating with a woman on a crescent moon.

Knowing that the pyramid would be further plundered once we left, we decided to open up a new section to methodical excavation, choosing a ten-by-ten-meter (1,076-square-foot) area near the summit. Here we came upon a place where the mud brick had been carved out and refilled in ancient times. Digging down, we found eight decomposed wood beams, similar to those that had roofed the looted burial

Between the first and eighth centuries A.D., the Moche occupied a series of river valleys, map left, along the otherwise arid coast of northern Peru. At Sipán, below, the Moche built three mud-brick pyramids, now much eroded. Excavations continue at the smallest of these (foreground), which concealed at least four royal tombs.
Bill Ballenberg

chamber. Buried beneath these, in the debris of what had been a small rectagular chamber, we found 1,137 ceramic bowls, jars, and bottles. They portrayed a variety of human figures: warriors holding war clubs and shields, nude prisoners with leashlike ropes around their necks, musicians with drums, and seated figures wearing beaded pectorals (biblike coverings). Some were arranged in symbolic tableaux, for example, musicians and prisoners ringing and facing noble personages.

As we removed the ceramics, we found several pieces of copper and, finally, a man's skeleton lying jackknifed on its back, with chin, knees, and arms pulled in toward the torso. Since the Moche customarily buried their dead in a fully extended position, we interpreted this individual to be a sacrificial victim, whose body had been shoved into the small chamber as part of the ritual offering.

Even as these offerings were being excavated, we discovered a second, larger rectangular area that appeared to have been carved into the pyramid and refilled. As we carefully excavated this, we found, about thirteen feet below the original surface of the pyramid, the skeleton of a man wrapped in a cotton shroud. He lay stretched out on his back and wore a gilded copper helmet. Over his right forearm, which rested on his chest, was a round copper shield. A little below we found the remains of seventeen parallel beams that, we dared hope, lay over a major, undisturbed burial chamber.

The discoveries that subsequently emerged surpassed our dreams. Buried in the chamber were the remains of a wood coffin that contained the richest grave offerings ever to be excavated scientifically in the Western Hemisphere. The body of a man between thirty-five and forty-five years of age had been laid to rest with a feathered headdress, banners of cloth with gilded copper decorations, beaded pectorals, nose ornaments and necklaces of gold and silver, ear ornaments of gold and turquoise, face coverings of gold, a gold backflap and a silver backflap that would have been hung from the belt, and countless other precious objects. In his right hand the deceased had held a gold and silver scepter topped with a large rattle, and in his left hand, a smaller scepter of cast silver. In relief on the rattle, which was shaped like an inverted pyramid, were scenes of an elaborately dressed warrior subjugating a vanquished opponent. The sculpted head of the smaller scepter echoed this theme.

Working six days a week, it took us four months to document and safely empty the delicate contents of the tomb. As our original budget became exhausted, we received some partial funding from a brewery and a truckload of noodles donated by a pasta manufacturer. At one point we were paying the fieldworkers with a combination of cash and noodles. We eventually secured new support from the Research Committee of the National Geographic Society and were able to proceed with further excavation.

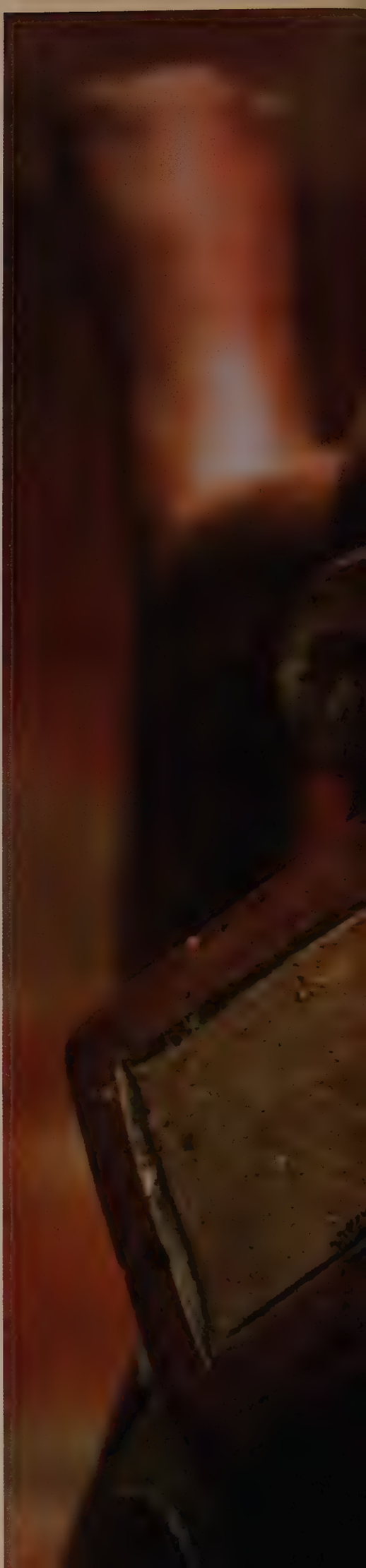
All the while we had been working and moving equipment around the coffin burial, we had been walking only inches above hundreds of ceramic vessels, two sacrificed llamas, a dog, and the burials of two men, three women, and a child of nine or ten. Although we do not know this for sure, the men and the child might have been buried as sacrifices to accompany the principal figure. The remains of the females, however, were partly decomposed at the time they were placed in the tomb, as evident from the way the bones were somewhat jumbled. They had probably died years earlier and their remains maintained elsewhere until this final interment.

As we excavated the tomb and cataloged its contents, we couldn't help wondering who was the important personage buried there. The key to the answer was a major photographic archive of Moche sculpture and drawings at the University of California at Los Angeles. As the tomb was being excavated, photographs of the objects were sent to UCLA for comparative study.

Many of the objects in the coffin suggested the man buried there was a warrior. The archive of Moche art contains hundreds of depictions from which we can reconstruct a sequence of Moche militarism and ceremonial activity. We can see processions of warriors carrying war clubs, spears, and spear throwers, perhaps on their way to battle. We can see warriors in combat, apparently away from settled areas. The essence of Moche combat ap-

A gold and silver necklace of peanut-shaped beads belonged to the warrior priest buried in the first royal tomb to be scientifically excavated. The Moche probably associated gold with the right side and masculinity, and silver with the left side and femininity.
Susan Einstein

Looted from an unknown grave, a Moche vessel depicts a warrior seizing his adversary by the hair and subduing him with his club. Moche engaged in combat to obtain prisoners for ritual sacrifice.
Nathan Benn © National Geographic Society



pears to have been the expression of individual valor, in which warriors engaged in one-on-one combat, seeking to vanquish, rather than kill, an opponent. The victor is often shown hitting his opponent on the head or upper body with the war club, while the defeated individual is depicted bleeding from his nose or losing his headdress or other parts of his attire. Sometimes the victor grasps his adversary by the hair and removes his nose ornament or slaps his face.

As far as we can tell, the Moche warriors fought with one another, not against some foreign enemy. Once an opponent was defeated, he was stripped of some or all of his clothing and a rope was placed around his neck. The victor made a bundle of the prisoner's clothing and weapons and tied it to his own war club as a trophy. After a public parading of the spoils, the prisoners were arraigned before a high-status individual and finally brought back to the Moche settlements or ceremonial precincts. There the priests and their attendants sacrificed them, cutting their throats and drinking the blood from tall goblets. The bodies were then dismembered and the heads, hands, and feet tied individually with ropes to create trophies.

Many representations of the sacrifice ceremony exist in Moche art. Although

Only three and three-quarters inches in diameter, one of the warrior priest's ear ornaments portrays a warrior complete with a war club, shield, headdress with its crescent-shaped decoration, and ear ornaments of his own.
Susan Einstein

A design from a Moche ceramic bottle depicts the Moche sacrifice ceremony. The conical helmet with a crescent-shaped ornament on one of the larger figures (left) helps identify him as a warrior priest. He holds a goblet of blood taken from sacrificed prisoners, who are shown beneath having their throats cut.
Donna McClelland

they vary, not always depicting all personages in the ceremony, apparently three principal priests and one priestess were involved, each associated with specific garments and ritual paraphernalia. The most important was the "warrior priest," generally depicted with a crescent-shaped nose ornament, large circular ear ornaments, a warrior backflap, a scepter, and a conical helmet with a crescent-shaped ornament at its peak. A comparison of these and other details with the contents of the tomb convinced us that the individual buried there was just such a warrior priest.

When the sacrifice ceremony was first identified in Moche art, in 1974, no one could be sure it was a real practice, as opposed to a mythical event. Now we had archeological evidence that this was an actual part of Moche life. Here was one of the individuals who presided over the sacrifices. Further, because the limited number of objects salvaged from the looted tomb were similar to some of those we had excavated, we could conclude that the looted tomb also must have belonged to a warrior priest.

As if this were not enough, during the excavation of the warrior priest's tomb, we located another suspected tomb elsewhere on the pyramid. We held off excavation until work on the earlier find was nearly complete. The knowledge we gained made it easier to anticipate the sequence of excavation. Again we found the residue of a plank coffin containing the rich burial of a man between thirty-five and forty-five years old. Among his grave goods was a spectacular headdress ornament of gilded copper, in the form of the head and body of an owl from which arched long bands with suspended bangles, representing the feathered wings. Nearby we found the remains of four other individuals: a male between fourteen and seventeen years of age, two females in their late teens or early twenties, and an eight- to ten-year-old child. Buried with the child were a dog and a snake.

The contents of this tomb were only a little less lavish than those of the warrior priest. They suggest that the principal individual was another of the priests depicted in the sacrifice ceremony—one we call the "bird priest." The major clue was the large owl headdress. He was also buried with a copper cup near his right hand, similar in proportion to the cups portrayed in pictures of the sacrifice ceremony.

Having identified these individuals as participants in the sacrifice ceremony, we began to wonder if such ceremonies took place in Sipán itself. The answer was soon revealed when, about eleven yards from the bird priest's tomb, we found several small rooms that contained hundreds of ceramic vessels, human and llama bones, and miniature ornaments and implements, mixed with ash and organic residues. Among the human remains were hands and feet, quite possibly the trophies taken from dismembered sacrificial victims. Altogether these looked to be the residue of sacrifice ceremonies, which the Moche apparently carried out at Sipán, as no doubt they did at their other centers.

The looted tomb, the two excavated tombs, and the sacrificial offerings all

Crafted of gold, a spider with a body in the form of a human head sits in the middle of its web. This intricate bead contains three small gold balls, here hidden from view, that gave it a rattling sound.
Susan Einstein

seem to date to about A.D. 290. While excavating the offerings, we found a fourth, somewhat earlier tomb containing the remains of a man between forty-five and fifty-five years old, also richly endowed with grave goods, including a necklace of gold beads in the form of spiders on their webs, anthropomorphic figures of a crab and a feline, scepters, an octopus pectoral with gilded copper tentacles, and numerous other ornaments and objects. Nearby we found the body of a young, sixteen- to eighteen-year-old woman next to a sacrificed llama. This tomb may also have belonged to a warrior priest, but not all the identifying elements are there. Possibly, this is simply because it dates to an earlier period than the depictions we have of the sacrifice ceremony, which are all from after A.D. 300.

Moche civilization collapsed suddenly, probably as a result of one or more of the natural cataclysms that periodically devastate coastal Peru—earthquake, flooding, or drought. The Moche had no writing system, so they left no records we can hope to decipher. They disappeared before Europeans reached the New World and could leave us eyewitness accounts. Yet with the scientific excavation of these royal tombs, we have gained an intimate portrait of some of their most powerful lords. Work at Sipán continues, now at a promising location near the tomb of the bird priest. As we dig more deeply, we look forward to our next encounter. □

Royal Tombs of Sipán, a special exhibition detailing the 1,700-year-old burials excavated from a Moche pyramid, will appear at the American Museum of Natural History from June 24 until the end of the year. Organized by the Fowler Museum of Cultural History at the University of California at Los Angeles, the exhibition features 115 artifacts of gold, silver, turquoise, and other precious materials on loan from Peru's Brüning Museum.

A necklace of gold spider beads was one of the last objects placed over the principal burial in the third intact tomb. Many other gilded copper ornaments have turned green with corrosion.

"Dear Enemy" Notes

A neighbor's song means more than music to a hooded warbler's ears

by Renée Godard and Haven Wiley

On a balmy April morning, the bottomland hardwood forests near Chapel Hill in central North Carolina are deceptively peaceful. As we stand in the dense understory of arrowwood, with its pale new foliage, two black-and-yellow sprites fly furiously back and forth across an invisible boundary. They are so oblivious to our presence that they almost brush our legs in passing. After about ten minutes of this twisting through the arrowwood, the tiny birds separate by some fifty yards. Each takes a station just below the crowns of the oaks and hickories and begins to belt out its own version of a ringing song. The black cowls over yellow faces reveal that these rivals are male hooded warblers. They have come to the forest to begin the breeding season.

One of the birds wears two lightweight, red plastic bands on each leg. He was one of the first males we banded for identification here at our study site, the Mason Farm Biological Reserve, and he has returned to exactly the same location in this 370-acre woodland for the fourth consecutive year, an exceptional record. His rival, as yet unbanded, is probably less than one year old and is staking a territorial claim for the first time.

Like many migrating songbirds, hooded warblers spend the winter in warmer climes. They winter from Mexico to Panama and begin to make their way north in March. By April, they have reached their summer quarters, which extend from the Gulf coast north to southern Michigan and east to Connecticut. The birds we have been observing have each just returned from their Mexican and Central American retreats and are now in serious competition for real estate. Their female counterparts will arrive in about five to ten days. To attract a mate and eventually raise healthy young, each male needs a territory of some twelve to twenty-five acres of forest with a luxurious understory of shrubs like arrowwood. The old-growth bottomland forests in the Reserve are an ideal habitat; each year five to ten hooded warbler pairs nest here. Only about half of these birds, however, survive the winter and round-trip migration from one year to the next. The color-banded old-timers are among the first to return, and each quickly reclaims his former territory. In contrast, newcomers ready to breed for the first time must find an opening vacated by a male that failed to return. This precise "site-faithfulness" of returning males is one of the remarkable features of migration for many songbirds. Why should males not move from one year to the next? After all, they might have settled for an inferior territory the first year they bred; surely some of them could upgrade their location in a subsequent year.

Part of the answer lies in the relationships of neighbors. Male hooded warblers, like many other male songbirds, have a number of ways of dealing with rivals in adjoining territories. The simplest interaction of neighboring males is simply singing within earshot of one another. Our systematic observations have shown that the average male hooded warbler spends 55 percent of each early spring morning just singing. When, on occasion, a male meets a neighbor at a disputed boundary, singing ceases and chasing begins, sometimes escalating to fighting. When the females arrive, aggression intensifies. Intermittent chasing can last for two days before both parties tentatively accept a boundary. But once boundaries are established, neighbors quickly develop a respect for them. Males can then sing close to the edge of their territory without provoking an attack from a neighbor. Such apparent amicability does not, we have noticed, prevent them from occasionally venturing surreptitiously into one another's territories.

The birds have become what evolutionary biologists have termed *dear enemies.* Instead of constantly battling, two individuals appear to call a truce; while not becoming allies, they can at least avoid continual contests. Our studies suggest that an important factor of this détente is the hooded warbler's ability to recognize a neighbor's songs. Each male's repertoire consists of five to ten stereotypical patterns of notes. Each song is recognizable

A male hooded warbler refreshes himself in a Texas stream.
Barth Schorre; Bruce Coleman, Inc.

A female hooded warbler, left, arrives at the species' breeding grounds about a week later than the first males. For an early spring male migrant, below, a still-bare branch in New York City's Central Park provides a perch from which to dart out and catch insects. If males return too early, cold and scarcity of insects can be deadly. But if they arrive too late, all the best territories will be taken.
Arthur Morris

as a hooded warbler's—although some do not come very close to the descriptions in standard field guides—yet each has at least a few details that make it characteristic also of the individual.

The ability of male songbirds to discriminate the fine, individual differences in the songs of rivals, both known and new, was established through experiments several decades ago. Our experiments with hooded warblers in the Mason Reserve since 1987 have demonstrated that these birds are even more discerning. A male hooded warbler can recognize the songs of each one of his neighbors and can also learn their usual locations in relation to his territory. To demonstrate this ability, we chose twelve hooded warblers from the Mason Reserve and adjoining woodlands as study subjects. First, we played a tape recording of a neighboring warbler's songs just inside a subject's territory near the boundary shared with that neighbor. Then we broadcast the same tape, also just inside but now on the opposite side of the subject's territory, near a boundary shared with a different neighbor. (Because in an experiment of this sort, the order of presenting the two playbacks might influence the results, we played neighbors' songs to half of the subjects in reverse order.) Subjects often quickly approached the speaker and searched frantically for the apparent invader. However, our subjects responded much less vigorously to neighbors' songs coming from the expected direction than to the same songs emanating from the opposite direction. Hooded warblers, then, know each neighbor's songs, and know just where they should come from. To our subjects, a playback of a neighbor singing on the wrong boundary signaled a serious territorial invasion.

Many ornithologists have noticed that former neighbors returning from winter quarters act like dear enemies right from the start. As with our red-banded male that early spring morning, returning males are more likely to dispute boundaries with new birds. Do returning neighbors just remember old boundaries, or are they capable of remembering one another's songs? The latter feat would be remarkable: the birds have had no chance to hear the songs for more than six months. They do not sing for most of the winter. We also know that hooded warblers from the Mason Reserve do not migrate together because they do not arrive at the breeding grounds together. Nor, presumably, do they winter together in Mexico and Central America.

To test song memory, we duplicated the experiments just described, with an added element. We started our tests on the very day a male appeared in April on his previously occupied territory. Familiar songs of neighbors from the year before, played near the old boundary, elicited little response; to our subjects they must have sounded like an old friend back in his usual place. In contrast, the same songs played near the "wrong" boundary evoked a strong response—a quick approach and frenetic searching. Male hooded warblers do, in fact, remember each neighbor's songs from one year to the next. These birds provide one of the few demonstrated cases of long-term memory in a nonhuman vertebrate. This ability has important practical consequences for a hooded warbler. By returning to precisely the same territory year after year, a male can expect to avoid "bargaining" for boundaries with about half of its neighbors. The time and energy thus saved can be used to deal with other neighbors and to attract and court a female.

A male reacts strongly to a trespass into its territory, a transgression that amounts to an abrogation of a mutually accepted treaty. Does such a trespass have consequences beyond a chase by the subject male? Evolutionary theory predicts that it should. A dear enemy relationship involves reciprocal respect for an arbitrary boundary. Such reciprocity in a potentially exploitative relationship can persist when rivals play tit-for-tat. Rivals must recognize each other individually, so they can keep track of each other. They also must interact repeatedly over an indefinite period of time, so neither can take advantage of the other on their last interaction. Finally, each must retaliate whenever the pact is broken. Our warblers met the first two conditions, and we devised another test to determine if trespass provoked retaliation by the offended male.

We first presented a neighbor's songs

Russ Kinne; Comstock

Hooded warblers frequent the understory of woodlands. A male in Point Pelee, Ontario, near the extreme northern edge of the hooded warbler's range, peers at sprigs of poison ivy, right. Below: A pair share in the care and feeding of their young, which are within two days of fledging.

George K. Peck

near the "correct" boundary of a subject's territory. As expected from our previous experiments, the subject's response was weak, the normal result for a dear enemy. Then this same neighbor's songs were broadcast from two locations deep inside the subject's territory (we stopped the playbacks as soon as the subject arrived nearby, so it would not learn that the neighbor was not actually present). Following this simulated trespass, we once again presented the same neighbor's songs near the correct boundary. The result was clear: a subject responded much more strongly to a neighbor's songs following an apparent trespass. When we staged trespasses with a stranger's songs, retaliation toward a neighbor did not occur. Retaliation was therefore restricted to the trespassing individual, just as predicted for rivals playing tit-for-tat.

Over the years, we have come to appreciate the intricate lives led by hooded warblers. They know their neighbors and work out mutually advantageous relationships with them. The trust required for these relationships, however, is not "naïve." While not demanding "an eye for an eye" following trespass, they do become antagonistic toward wayward neighbors. We have also noticed that in the days following a simulated trespass, our subjects' behavior returned to normal. Given a little time, warblers appear to "forgive" their trespassers.

What we have found could well apply to other migratory songbirds that defend territories during the breeding season. If so, our studies suggest another way in which habitat destruction can have devastating effects on populations of migrating birds. For a surviving male hooded warbler headed north for the summer, not all habitat, not even habitat suitable in general for the species, is optimal. Each individual seeks out the one specific place where it has an advantage—its territory from the previous year, where it will meet some of its old neighbors. If a particular stretch of forest has disappeared, our individual migrant must start over.

April is a time of blossoming opportunities. For the hooded warblers arriving on each southerly wind, it is also a time of establishing and renewing relationships, including those with their neighbors. By mid-May, most males in the Mason Farm Biological Reserve will have mates incubating three or four eggs in nests cradled on stems of arrowwood. Those nests that escape predators and cowbirds (about half of the total built) will produce a new generation of hooded warblers to carry on the tradition of dear enemies. □

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Owl monkeys have evolved big eyes to help them get around after dark. Not as well adapted to the nighttime as many nocturnal mammals, they are most active on bright moonlit nights.
Tom McHugh; Photo Researchers, Inc., Monkey Jungle, Miami

Night Watch on the Amazon

When dusk falls in the Peruvian rain forest, the world's only nocturnal monkey gears up for a noisy night of feeding in the canopy

by Patricia Chapple Wright

The full moon loomed above the Peruvian rain forest canopy, illuminating even the forest floor where I sat with my field notebook in hand. On this chilly and quiet night, I strained my ears to catch every sound. Suddenly, coming from some one hundred feet up in the canopy, I heard what I was waiting for: the low, mournful hoot of an owl monkey, *Aotus trivirgatus*. Three notes, a pause, and then a lower note. Taking a compass direction, I wrote down the time. The call was repeated for the next ten minutes, then stopped. From a distance came the answering call: five gruff hoots, a pause, and two lower hoots.

I had been listening to calls like this on bright, moonlit nights for almost a year and had begun to piece together certain aspects of owl monkey life. I knew, for example, that these owllike calls are given by a monkey when it is alone, usually near the borders of its family's territory. Calling sessions are restricted to once or twice a month and may be given by an adult male, an adult female, or a subadult. The calls, which can be heard 1,500 feet away, consist of a series of ten to thirty short, low-pitched hoots a minute. The session lasts one to two hours, as the caller moves a few hundred feet along its border. The calls almost always evoke responses from neighboring territories. At the end of this territorial calling session, a calling monkey usually returns to its family, which may be resting in the center of the territory. When a young monkey leaves its natal group, however, it may travel long distances in the forest, calling continually, perhaps advertising for a mate.

As glad as I was to begin deciphering owl monkey calls, no call could tell me what I had come to Peru to find out—why this species is active at night. Found in forested regions from Panama to northern Argentina, it is the world's only nocturnal monkey. All other nocturnal primates—including mouse lemurs and aye-ayes in Madagascar, tarsiers and loris in Asia, and bushbabies and pottos in Africa—are prosimians, a more primitive group that lacks the monkeys' relatively large brain, enclosed eye sockets, dry rhinarium (nose), and impressive manual dexterity. And unlike the eyes of most nocturnal mammals, the owl monkey's eyes have cones for color vision and lack a reflective shield on the retina (the tapetum lucidum), which suggests that its ancestor was active in the daytime only. A question that had long intrigued scientists was why a day monkey had evolved into a night monkey. Since studying monkeys in captivity or skins in a museum could not give satisfactory answers, I decided to go to the Cocha Cashu research station, situated in a pristine rain forest in southeastern Peru's Manu National Park, where I could observe owl monkeys in the wild.

The owl monkey shares its rain forest home with eleven other monkey species, including *Callicebus moloch,* the dusky titi. The diurnal titi and the owl monkey—both about squirrel size—have similar social systems. I decided to compare the life styles of the two species—their diet, sleeping habits, movement patterns—in the hope of gaining insight into the owl monkey's nocturnal life style.

I first needed to survey the area for both species of monkey and to select four groups (two of each species) to focus on. I chose one group of owl monkeys whose territory bordered on the Manu River and another whose territory bordered on Lake Cocha Cashu. Then I identified titi territories that overlapped with the chosen *Aotus* groups. With my study animals targeted, I then began the lengthy process of getting them used to my presence and learning how to follow them through the forest.

Owl monkeys are often habituated to one sleeping tree. Charles Janson, a primatologist studying capuchin monkeys at Cocha Cashu, was the first to find an *Aotus* sleeping tree there. I began my real data

Owl monkeys often sleep and seek shelter in tree holes and vine tangles.
Arthur W. Ambler; Photo Researchers, Inc.

collection sitting under this tree with my binoculars and notebook. Just as dusk fell, the first owl monkey—a male—emerged from his secluded den in the center of the tree and began to scratch himself. Seconds later, three other owl monkeys appeared. From their size, I presumed these three were his mate, an adolescent, and a half-sized juvenile. They spotted me immediately and began to give an alarm call, but they didn't flee. After ten minutes, they began to move on through the canopy. I followed, but by this time it was dark. They were moving quickly and soon disappeared from my view.

Dusk after dusk, I returned to the tree and followed the group as far as I could. Each night, I went a little farther. I cut narrow trails under their arboreal pathways. I listened carefully as group members exchanged contact calls. I was grateful that they dashed carelessly through the trees, making abundant noise as they jumped from branch to branch. Still, several months passed before I could follow them all night long.

During the day, I began tracking the dusky titis. I had a different problem with them. Although they moved much lower in the trees than the owl monkeys (an average of thirty feet above the ground), they were dark and blended into the foliage. They were also cautious in their movements, nearly impossible to hear as they jumped from branch to branch, and they often rested, hidden in tangles of vines. I had hoped that the titis would be the easy part of my fieldwork, but I was often frustrated during the first two months of my effort to keep track of them.

Eventually, however, I could follow both day- and night-monkey groups. I couldn't, of course, keep going twenty-four hours a day, so I developed a routine. First, I would spend five days with the owl monkeys in Group One, following them from dusk to dawn. Then I would switch to five days with dusky titi Group One, this time from dawn to dusk. After that, I'd move on to owl monkey Group Two for five days and finish up with a round of five days with titi Group Two. With such constant disruption to my circadian rhythm, I felt as if I had jet lag for the entire year.

The work proceeded well, but since I was not using radio collars, I was continually plagued with the problem of losing track of the owl monkeys. One night, for instance, they quietly left a large fig tree without my detecting them. When I real-

Carol Farneti; Natural Science Photos

Common in the open Chaco forests of Paraguay, nocturnal great horned owls, left, are capable of carrying off small monkeys. There, the otherwise noisy owl monkey, below, moves more cautiously and quietly than in the rain forest.

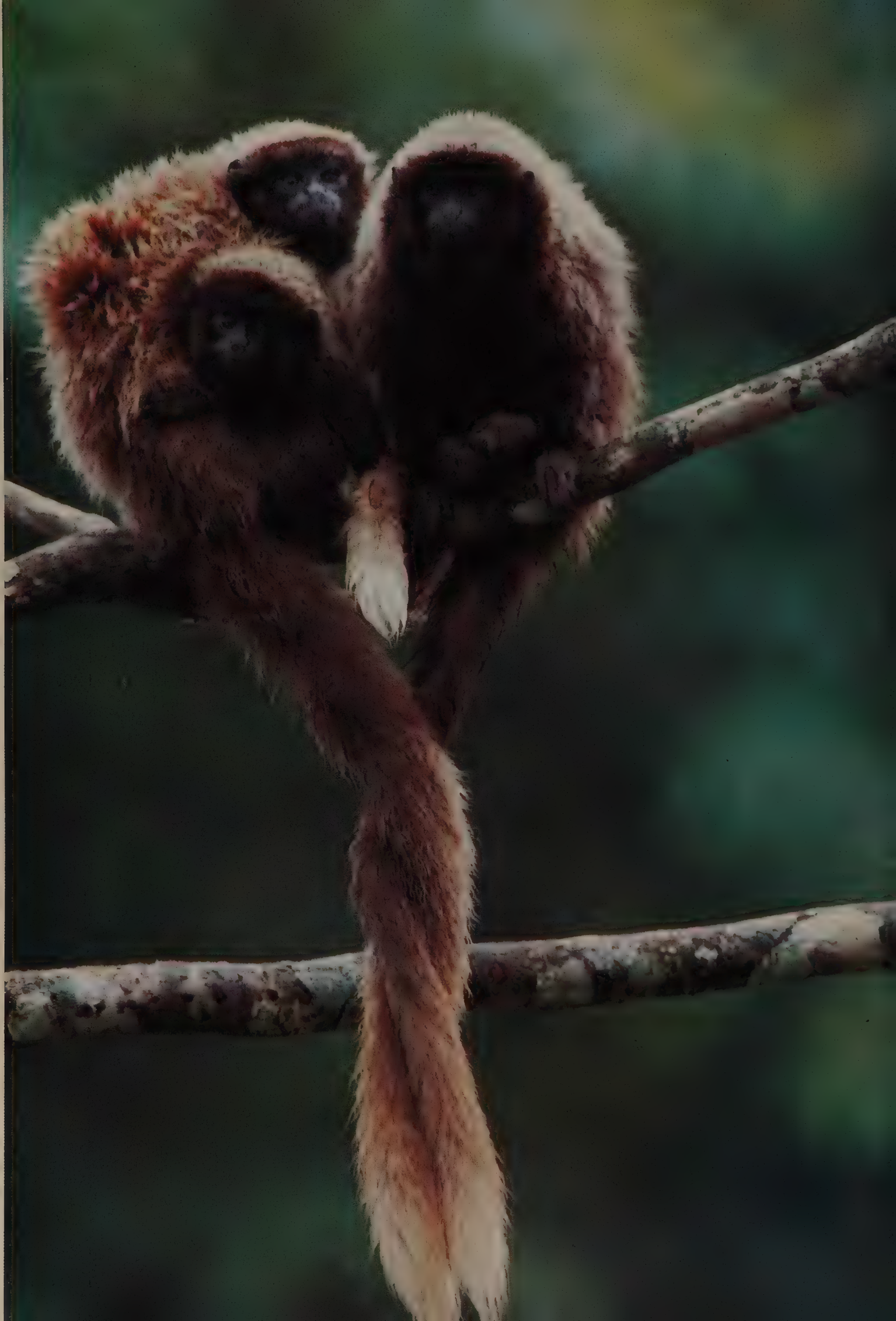
Charles Janson

ized they were gone, I reasoned that they had journeyed to the next fig tree, which I knew was about a thousand feet along the river trail. I moved quickly along the trail, making little noise since the leaves beneath my feet were wet from rain that had fallen earlier in the day.

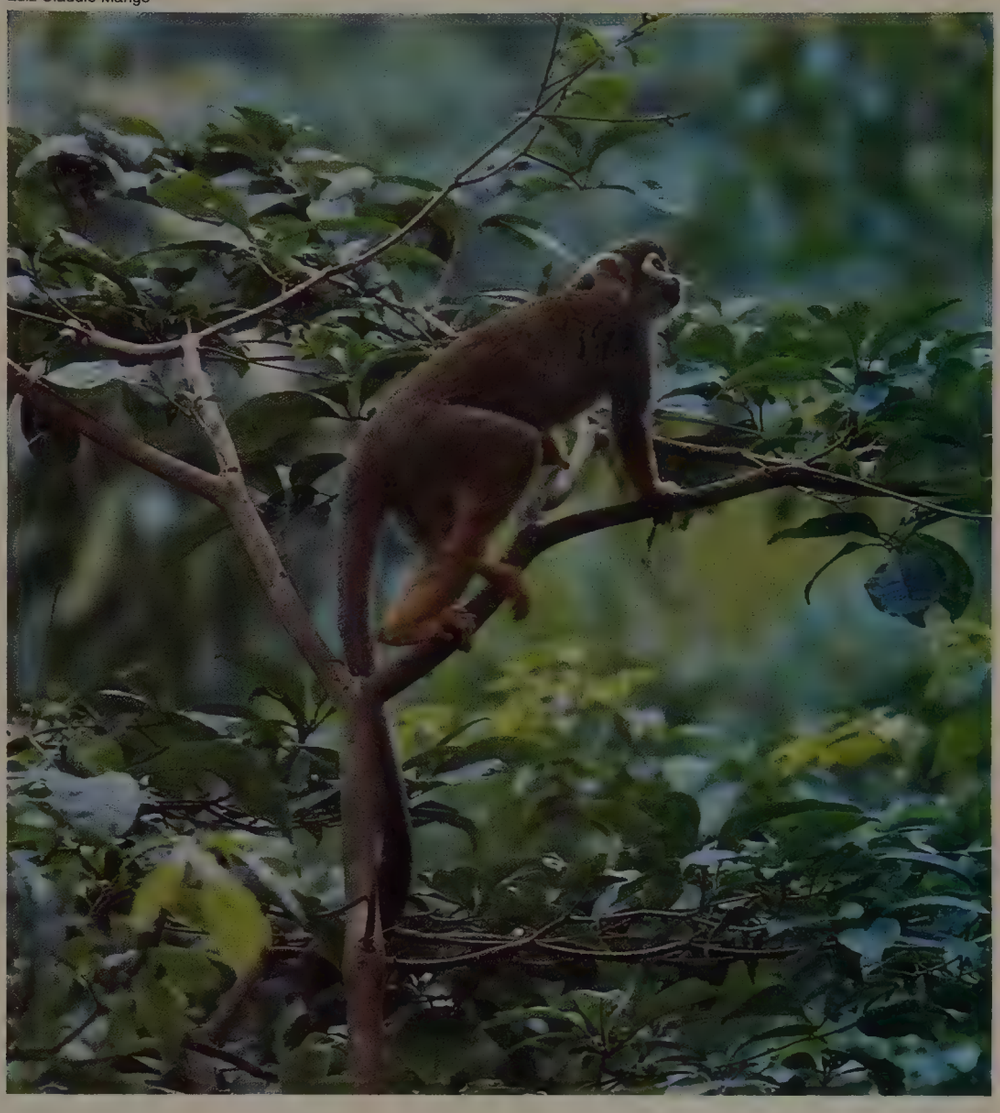
But I wasn't the only one walking quickly and silently along the river trail. As I rounded a bend, I suddenly stood face to face with a large male jaguar. We were less than three feet apart. My headlamp temporarily blinded him, and he blinked five times. I moved slightly off the trail to give him the right of way. At the sound of my movement, the jaguar bounded into action, but—I noticed in a daze—away from me, back into the jungle. I listened as he continued to move into the distance. Suddenly, I was afraid. My heart raced, and I decided to give up monkey watching for the evening. Instead, I visited each tent of sleeping researchers, warning them that a jaguar was in the neighborhood. The next day, we were impressed by the large size of the footprints, but we never saw the jaguar again. He had apparently moved on to another part of his large territory.

Most of my evenings were less eventful, and after a year, I had accumulated basic data about the two species. In both, territory size ranged from seventeen to thirty-four acres. The distance the owl monkeys traveled in one day was 2,100 feet on average; the titis moved an average of 1,950 feet. The average group size of both—five animals—was also similar and included an adult male and female, one adolescent, a juvenile, and an infant. The adults are monogamous, and their offspring remain with the group until they are three, at which time they disperse, usually in the rainy season. Finally, as with most primates, both species ate a combination of fruits, leaves, flowers, and insects.

But the two species also differed in



Like the owl monkey, the dusky titi, facing page, is monogamous and lives in small family groups. It forages in the daytime, however, and is forced to compete—often unsuccessfully—with squirrel monkeys, below, and other monkeys living in Peru's Amazonian rain forest.
Luiz Claudio Marigo



many ways. One of the dusky titi families, for example, slept in a total of forty-three different trees over the course of the year, while owl monkey families used no more than five. As they slept on open branches, the titis were visible from below, whereas the owl monkeys were always hidden from sight as they slept in a tangle of vines or in a tree hole. *Callicebus* was quiet, vigilant, and cautious as it foraged low in the trees during the day; *Aotus* was noisy and careless as it went about its business high in the canopy at night.

I began to suspect that the daytime presented some dangers that the nighttime did not. Circumstantial evidence soon implicated birds of prey as a probable daytime threat. From studies conducted by ornithologist N. Rettig of remains under the nest of a harpy eagle in Guyana, we knew that monkeys were the main item in this eagle's diet. Manu National Park is home to six species of hawks and eagles, including the harpy, that are big enough to eat owl monkeys and dusky titis. During the third month of my research, a harpy eagle was sighted carrying a squirrel monkey in its talons. A few weeks later, a crested eagle attacked a group of capuchin monkeys. And one of the young titis born the year I started my study was last seen in October of his second year in the talons of a crested eagle.

Also suggesting that the monkeys were responding—although in different ways—to the threat of predation were the times monkeys entered and left their sleeping trees. The titis were irregular. Between October and May, when it was warm and fruit was abundant, they would get up at about dawn, but when the weather grew colder, they would stay in their roost until noon. This flexibility fit in with my theory that while escaping predators was crucial for these diurnal monkeys, it was *how* they foraged—quietly, low down—that was important; *when* they foraged was not.

The owl monkeys couldn't have been more different. They regularly left the sleeping tree a few minutes after sunset (after hawks and eagles would have gone to their roosts) and returned to it a few minutes before the sun rose (and diurnal birds of prey awoke). This precision, too, fit my theory, with the monkeys behaving—I fancied—as if they were afraid that if they got up too early or stayed out too long, they might wind up as a meal for some hawk or eagle.

But what about nocturnal predators? Owls were of no concern, as my ornithologist colleagues explained to me, for large species, such as the great horned owl, are scarce in tropical forests of South America, and none of the other owls in the Amazon rain forest were big enough to eat a squirrel-sized monkey. Other nocturnal predators, such as cats and snakes, were primarily terrestrial and no match for an agile monkey in the trees.

Foraging at night may do more for owl monkeys than reduce the risk of being killed by a predator. Different monkey species compete strongly for fruit trees, particularly in the season of fruit scarcity. My data showed that spider monkeys, capuchins, and even squirrel monkeys—all species that are either bigger than the titis or travel in larger groups—are able to chase the titis away from large fig trees. This forced the titis to subsist at this time of year almost exclusively on leaves, which are difficult to digest. The owl monkeys, in contrast, fed in the large fig trees without harassment. Their only nocturnal competitors were opossums and kinkajous. I once observed an owl monkey approach an opossum feeding in a tree; to escape, the small opossum dropped sixty

Luiz Claudio Marigo

Harpy eagles, below, regularly prey on small monkeys of the Peruvian rain forest. The heftier red howler, right, weighing several times as much as a titi or squirrel monkey, rarely winds up as a meal for one of the forest's diurnal birds of prey.
Ken Lucas; Planet Earth Pictures

feet out of the tree, landing at my feet. Kinkajous, at five pounds nearly twice the size of an owl monkey, are not so easily dominated. However, kinkajous are solitary and thus would be no match for a group of four to five owl monkeys; when these two species meet, they usually move apart to feed in different parts of the tree.

To test my theories about the owl monkey's nocturnal life style, I decided to observe the species in a different sort of habitat. After my year in the rain forests of Peru, I visited the dry, open forests of the Paraguayan Chaco. Few diurnal monkey species live in the Chaco, and none of the species that had attacked *Callicebus* in Peru. Diurnal raptors are also rare, but great horned owls are common. One pair raised two young in a nest near my campsite during my time there.

Interestingly, I found that owl monkeys in the Chaco had reverted partly to daytime activity. I watched in amazement as the monkeys browsed on flowers and fruits at the top of the canopy in bright sunlight. They foraged at night as well, but now they moved quietly and avoided the upper canopy, where they would be exposed to the owls. On average, the owl monkeys traveled and foraged one to three hours in daylight and some nine hours at night. In the cold Chaco winter, during the times of the month when there was no moonlight, the monkeys increased their daytime activity, traveling nearly as far in the daytime (850 feet) as in the night (about 1,000 feet). The monkeys' sleeping patterns changed in the Chaco, too. They slept on open branches, not in hidden vine tangles, and used many different sites; one group slept in forty-two different trees in five months. Moreover, they were never chased from a fruit tree, day or night, with their only possible food competitor being *Alouatta,* the howler monkey. Overall, the behavior of the Chaco owl monkeys seemed to support the idea that avoidance of predators and food competitors may have played a role in the evolution of a nocturnal life style in the Peruvian rain forest.

If being active at night can, under the right circumstances, confer so many advantages, why haven't more monkeys adopted it? Most nocturnal mammals, including the nocturnal primates in Asia and Africa, have the tapetum lucidum, which allows them to see in the dark. Monkeys, apes, and humans have lost the tapetum and thus are relatively helpless at very low light levels. A short walk at night without the aid of a flashlight will show just how serious a loss this is.

How, then, does *Aotus* manage? Over the course of its evolution, the aptly named owl monkey evolved very large eyes, which assist it greatly as it searches for food in the dark and jumps from branch to branch high up in the canopy. Some of my findings, however, indicated that the monkeys' movements were restricted by low light levels. On totally dark nights, the owl monkeys I followed in Peru traveled nearly a thousand feet less than on clear moonlit nights; they also tended to stick to the most familiar paths. Certain activities—such as playing, territorial fighting, and calling—are engaged in only when the moon is bright. I gradually realized that I was not alone in my nightly stumbles through the rain forest; even for the successful owl monkeys, night life had its disadvantages. □

Of Bedouins, Beetles, and Bloom

In the Judean desert, wildflowers roll out the red carpet to attract pollinators

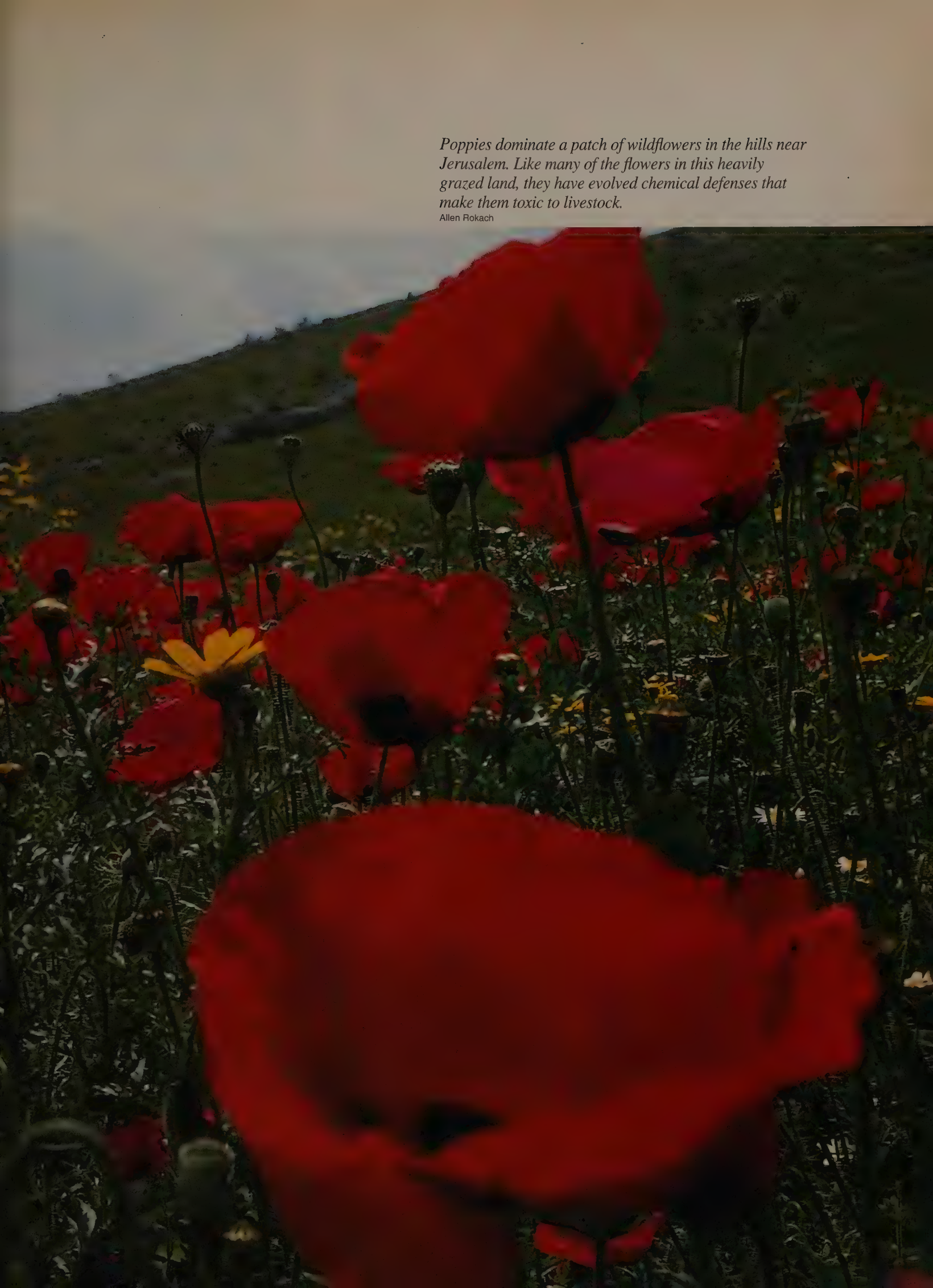
by Bernd Heinrich

The winter had been an unusual one. A tenth of an inch of snow and rain—two and a half times the average precipitation—had fallen on the Judean desert. In late March, two months of springtime weather remained. The nights were pleasantly cool, the days warm, and the land refreshed with rains. Rain means life in this small desert, which stretches from 1,200 feet below sea level in the east, where it borders the Dead Sea, to 2,400 feet at the water divide about twelve miles to the west. Along this transect of bare and rocky hills are such well-known biblical sites as Jerusalem and Bethlehem, as well as lesser-known towns such as Beit Fajjar, Abu Dis, Ramallah, and Bir Zeit.

Average precipitation is, however, not what this land sees. Rainstorms are erratic events, and despite this year's winter "excess," the desert would soon be dusty and parched again. The eastern slopes of the north–south-ranging hills lie in the rain shadow of the moisture-laden winds coming from the Mediterranean, another twenty to twenty-five miles to the west. Maps show numerous blue lines going down to the Jordan River and the Dead Sea. But they are not rivers. At least not now. They are wadis, or washes. Most are flood channels that this spring were dry beds filled with rounded limestones.

It was cool, but the sun shone through the cloudy sky as my friend botanist Avishai Shmida, of the Hebrew University of Jerusalem, and I swung onto the paved road in Jerusalem and started our rapid descent east, down to the valley of the Jordan. In the Mediterranean environment near Jerusalem, Avi and his colleagues have cataloged 1,586 species of wild plants. Another 586 species were found in the desert.

Looking over the bare hills, I could scarcely conceive that such diversity existed in a land that was already being intensively used by humans thousands of years before Christ. The rounded limestone hills, terraced into horizontal strips of soil a few yards wide, were yielding grapes, olives, and vegetables in Roman times and long before.



Poppies dominate a patch of wildflowers in the hills near Jerusalem. Like many of the flowers in this heavily grazed land, they have evolved chemical defenses that make them toxic to livestock.
Allen Rokach

Allen Rokach

A lone poppy, right, blooms among unopened buds and seed capsules. Below: Buttercups in the Judean hills have bright scarlet petals. Although most species of buttercups and wild tulips are yellow, those growing in Mediterranean climate zones are commonly red.

Bernd Heinrich

Some of the terraces lay fallow now, or seemed to. But the olive trees in their gray-green foliage and the small almond trees, bare of leaves but covered with sprays of pink flowers, were obviously there as a result of human effort. So was the stonework that held up the terraced strips themselves. Plants here grow in wild profusion, with a mean density of forty species per square yard. Yet only certain types can survive and prosper under the exacting conditions imposed by the environment and humans. Wild trees, obviously, could not. And that exclusion opened a niche for others.

I had just visited the Western Wall, the remnant of the Third Temple built by King Herod (or rather, his slaves), where the cracks between the giant, symmetrical blocks of limestone are stuffed with notes written by the devout. Seeing what people rest their hopes on had left me strangely depressed. But seeing these humble stone walls, holding up earth terraces at least as old as the walls and decorated with gorgeous pink cyclamen sprouting in the cracks, was uplifting. I felt the "cosmic optimism" of the naturalist—someone who, according to the definition of writer and entomologist Robert Michael Pyle, does not have an anthropocentric view of life. Pyle has pointed out that no matter what we humans can dish out, species that "know adversity and eat it up will endure." These flowers have survived the impossible, not so much in spite of us but perhaps because of us.

Deep blue grape hyacinths and bright red tulips grew "wild" along the lips and crannies of these ancient terrace walls. These, and others, were perennials, but at least half of the terrace plants were annuals—tiny herbs that thrived through time, not just because of the modest space they occupied but through their ability to lie dormant through long periods of drought, to be resurrected and to spring up again when sprinkled by rain.

In the valley of the Jordan, where pastoralists, rather than farmers, held sway, not a wild tree is left standing, and there probably have not been any since before the time of Christ. Sheep and goats and the inexorable human hand had seen to that. Now—as they have done for centuries—Bedouins tend flocks of sheep and goats that mow broad swaths over the land, nipping everything to the root. Indeed, the Bedouin is said to be not so much the son of the desert, as its father.

Nothing green or succulent has a chance to survive for long, unless it can retreat again into the ground in bulbs or tubers or unless it is poisonous or prickly. Such defenses are a competitive advantage against plants that don't have them (since grazers exercise choice in what they eat). But none is absolute. Perhaps the plants' most obvious and effective strategy against the grazers and the elements is to grow and flower quickly after the rare rains do come and then to revert quickly to dormant, drought-resistant seeds before the herbivores eat them. In short, the plants are often annuals.

Annuals are necessarily of small size. If conditions are right, then many individuals can exist side by side. But which ones? Why not all of one species, rather than many species? Avi tells me, "If it were not for the grazing, then the grasses would

quickly take over. They would crowd out many of the flowers." And it is not the grazing alone. The drastic fluctuation of rain within the winter period and from year to year reduces competition between species, so that no one species can take over and occupy every niche. What we might generally consider unfavorable conditions for plants are precisely those that have produced tremendous diversity.

As we descend farther into the valley, we can see the hills of the desert greening from the winter rains. From the window of our car, I see patches of yellow composite flowers, patches of light purple crucifers, and some white umbellifers. Above the background of yellow, white, and pale blue, there are also thick dots of red flowers, like flecks of shiny red blood upon the green.

A pleasing wash of colors from a bird's-eye view became a gorgeous mosaic when we parked and I saw it from a bee's eye level. But the beauty that was so striking to the eye was even more fantastic to the mind because behind the show lay a logic. That logic—that competition among pollinators that had helped to arrange the floral display—had first excited me two decades ago and a continent away. Here in the Judean desert was the same play, but all the players were different.

One step into this garden, which nature had been busily arranging for thousands of years (out of parts created over millions of years), I found much to admire. I saw a plant whose blue flowers had at their center tiny dabs of either white or pink. The dots were what Konrad Sprengler, the father of pollination ecology, called *Saftmale* (nectar guides). When white, they indicate (to experienced nectar shoppers) that the flowers are likely unvisited and contain nectar; when pink, they signal that the flowers are already drained (and hence pollinated).

I saw a small umbellifer whose white inflorescence with showy fringe florets

Allen Rokach

The various red-flowered plants of the Judean desert, above, stagger their peak flowering periods. Anemones bloom first, followed by tulips, buttercups, and poppies. Below: A crowned anemone is pollinated by three Amphiocoma *beetles.*

Bernd Heinrich

had an uncanny resemblance to that of hobblebush, a viburnum I knew from the Maine woods.

There was, in this plant community as in any other, a demand for flowers that were best suited to the specific tastes and physical requirements of the various pollinators. A broad, economic analogy applies. If there is a market in Israel for pizza, and there are no Italians around to make it, then even some Israelis might be induced to become pizza makers. The venture could be a risky one, but high risks can yield high rewards as well as extinction. In other words, beyond the plants' struggle for existence in the physical environment is a second fierce struggle among themselves to be serviced by the pollinators. Each gets pollinated by practicing a specific "line" or profession. As in Adam Smith's idealized free-market economy, specialization and "perfection" are the result of fierce competition.

In the vast sea of varied flowers stretching before me, not many "shoppers"—bees, flies, butterflies—were to be seen. Therefore, at least at this time, the plants were competing to attract pollinators. I casually followed one honeybee whose thorax was dusted with yellow pollen. It flew slowly without landing among the sea of yellow composites, blue-and-yellow mints, and pink stork's bills, passing also red anemones and white stars-of-Bethlehem. After several yards of careful search, it landed on an almost-hidden plant, a parasitic figwort with blue flowers and white nectar-guides on its lips. After a second or two, the bee came out of the deep flower, scraped pollen from its thorax, and then

patiently resumed its search for another flower of the same kind. The figwort, blooming close to the ground and isolated from others of its kind, was undoubtedly not visited by many shoppers. But those that found it—probably randomly at first—became flower constant, hooked on the good bargain because of its good crop of nectar. In the flower supermarket, the choices faced by bees are like those facing a human shopper—dozens of brands, all with different, showy labels.

Flowers must provide a good reward to insure repeat visits from a pollinator. In a meadow, as in a supermarket, competing product displays lure the buyer. But in the meadow, shoppers (pollinators) going down the "aisles" are free to snack. In order to keep them constant to any one brand, the manufacturer (the plant) not only has to advertise but also has to try to keep thievery (taking nectar without paying the plant with with pollen transfer) to a minimum. One way to do that is to limit access to the flowers. (Loyalty, or flower constancy, is important because each flower "wants" its pollen to be deposited in the stigma of its own kind, not that of another kind). Complex flowers are like puzzles, solvable only by those pollinators able to gain information denied others.

Perhaps no competitors are more bizarre than the Mediterranean *Ophrys* orchids. I had read about this group of a dozen or so species, each catering to a different, winged pollinator. Nevertheless, I was startled to have one pointed out to me at my feet. Barely six inches tall, its solid green stalk supported two exquisite, tiny flowers and three to four unopened buds. The flowers, about half an inch long, could be easily missed by the human eye, unless one knew what to look for. The two tiny flowers resembled bees. It didn't take great leaps of the imagination to see a small, bulbous, buzzy "abdomen" and even "wings" at each side. We have no idea what a bee or wasp sees, but the mimicry is undoubtedly much greater to the insect than it is to us. In mounting these flowers, male insects are probably attracted by the perfume, which in this case mimics the sex scent of the intended mate, but then orient themselves to the flower form.

I gently inserted the end of a twig to where I presumed the head of a copulating bee might reach, and when I withdrew it, it held a yellow packet of pollen such as a male might transfer to the next *Ophrys* it finds of that species.

Persian buttercup
Avi Hirschfield; ASAP

But in the end, the wild tulips (and other flowers like them) were what surprised me the most. Tulips had, before this, occasionally caught my interest, but only because of their shock value, their superfluous show. But these tulips were organisms in an ecological context where everything about them held meaning. If there was show, then that show was important beyond mere appearance, in the same way that a Hebraic text has significance; it is not just a page of attractive markings.

The bright red tulip stuck out like the proverbial sore thumb from the yellows, whites, and blues of the crowd. It offered only pollen, not nectar. The pollen-bearing anthers were almost black, as were the bases of the petals in the center of the cup-shaped flower.

This color pattern excited me because I had in the previous hour admired very similarly sized, shaped, and colored flowers of a quite different plant family. They had belonged to a poppy. The resemblance seemed too close to be accidental.

With my interest aroused, I examined red flowers more closely in the large patches that were everywhere. I found other red flowers with petals of a red so pure and brilliant they almost made me squint. As it turned out, they were buttercups, *Ranunculus asiaticus,* also known as Persian buttercups or scarlet crowfoot. I knew only the yellow-stamened, small waxy yellow *R. acris* flowers from back home, and these took me by surprise. I found still other flowers that seemed almost identical to those of the tulips, poppies, and buttercups—also large and bowl-shaped, with black stamens, and brilliant scarlet petals. These, Avi told me, were crowned anemones. What a contrast to the small, delicate, white-petaled anemones with yellow stamens in a Maine spring woodland!

A phenomenon so striking as these red flowers—all apparently mimicking one another—had not escaped the attention of local botanists, especially Avi. By 1981 he had already systematically studied and described the convergent evolution of the "poppy guild" of red flowers in the

Wild tulip
Allen Rokach

Mediterranean region of Israel. The group includes about fifteen species of large, red, bowl-shaped flowers of six genera from three plant families, and is dominated by poppies of two genera. The convergence is most striking when one considers how some of these flowers differ from their likely ancestors. *Ranunculus,* the buttercup, for example, has about 400 species worldwide. Only three, all in the Mediterranean region, are red. And all of these have cup-shaped flowers at least twice as broad as those of the predominantly yellow or white species. Wild tulips in Europe are also predominantly yellow, but in the Mediterranean region, red predominates. All poppy guild flowers provide only pollen, and no nectar, whereas some of their presumed progenitors also provided nectar. The various species do not, however, bloom simultaneously. Anemones are usually first, followed by tulips, buttercups, and finally, poppies.

Why did this very distinctive, red, bowl-shaped pollen flower evolve in so many different kinds of plants in one geographical area? From behavioral studies of bees, I had speculated that once a pollinator becomes "hooked" on one commodity of the market—such as red flowers—it could then be more easily exploited by other plants, provided they are rare or bloom slightly out of phase with their models. It is as if *A* has developed a market for pizza, but is unable to continue production after, say, April. In May, *B* can step in, utilizing an already-established market. If a product is a success, it will be widely copied as closely as possible (given the absence of patent laws).

But these red flowers are rarely pollinated by bees. Instead, they are primarily serviced by a group of scarab beetles of the genus *Amphiocoma.* Beetles had been thought to pollinate only flowers that smell foul and are white or greenish. But in an elegant and classical series of field experiments, Amots Dafni, of the University of Haifa, and six colleagues from other institutions reported in 1990 that these beetles have a relatively weak response to shape or scent, but exhibit a strong attraction to

Crowned anemone
Bernd Heinrich

the color red. Dafni and colleagues distributed unscented, flower-shaped plastic cups of various colors (red, blue, yellow, green, brown, white) in the field to serve as beetle traps. Of the 146 beetles captured, 127 were caught in red flower models. The remainder, eighteen beetles, were evenly distributed among the other colors. The researchers were also able to confirm their prediction that the beetles would be found in all of the red flowers of the poppy guild. *Amphiocoma* likely do most of the polli-

nating of these red flowers, since a visiting beetle carries away nearly 2,000 pollen grains (as opposed to a *Lasioglossum* bee, for instance, which carries, on average, only 110 pollen grains).

Red flowers probably have more to offer than food. Red color also advertises sex. Dafni and colleagues noted that the female beetles remained, on average, sixteen minutes in each flower they visited, whereas the males kept moving from flower to flower every three and a third minutes or until they found a female. Upon finding one, they immediately stayed to mate. Are the males searching for females in flowers?

The fuzzy, little, dark brown beetles with greenish or purplish thoraces are not always common. In one area near Jerusalem, I examined 1,548 *Anemone coronaria* flowers and found twenty-two that contained one beetle and eleven with more than one (primarily copulating pairs). Thus, only one in seventy flowers had a single beetle, whereas every flower with one beetle had a 50 percent chance of having another beetle. Put another way, a flower's chances of being visited again were thirty-five times greater if it already had a beetle in it.

I also noted numerous solitary bee males in the genus *Eucera* apparently sleeping in flowers. Indeed, under overcast skies, all of these bees stopped foraging and I saw up to six in a single flower. However, I never saw them copulating there. Their long antennae—almost as long as their entire body—attest that scent plays a large role in mate finding. In contrast, the antennae of the *Amphiocoma* beetles are microscopic in size. Although the beetles are nearly three-eighths of an inch long, the lamellae of their antennae are no larger than the dot a sharp pencil makes on paper. Their scent-organs seem almost atrophied, but their eyes are not: their attraction to red flowers finds them mates.

The sexes must meet somewhere. Why not while lounging at conspicuous, well-advertised places? And a female must lay up large protein stores to make eggs. For that she needs to eat pollen. Indeed, on two occasions during my brief survey, I saw male beetles land on flowers containing a beetle I was photographing, and in both instances the new beetle instantly attempted to mate with the beetle in the flower. Food rewards were apparently of only secondary concern for the males.

Thanks to fieldwork by Dafni and electrophysiological experiments by Randolf Menzel, of the Free University of Berlin, we know that these beetles (unlike most other insects, but like birds) evolved the capacity to see the color red. Once that occurred, the beetles could exploit the very conspicuous red signal of the flowers, resulting in enhanced mating success for them and for the plants they visited. Although we don't know for sure how the red flower guild serviced by beetles evolved, a likely scenario is that the plants imitated one another, and that many new products—like so many knockoffs of Swiss Army knives—entered the market, using the same distincive red signal in their advertising campaigns. In this case, the product being advertised was sex with breakfast in bed—a winning combination. And now the *Amphiocoma* beetles in the Judean desert enjoy the red carpet treatment, while we enjoy the show. □

The tremendous diversity of flowering plants in the Judean desert is partly the result of the region's drastic fluctuations in rainfall. In spring, the lush growth of flowering plants contrasts starkly with the treeless hills.
Allen Rokach

At the American Museum of Natural History

Opening of the Fossil Mammal Halls

The American Museum of Natural History launches its 125th-anniversary celebration with the opening of two of six new fossil halls on Saturday, May 14. Specimens in the Lila Acheson Wallace Wing of Mammals and Their Extinct Relatives include the mummified remains of a baby mammoth that lived 25,000 years ago, whose head, trunk, and leg were found "freeze-dried" in the Alaskan tundra; the ferocious bear-dog *Amphicyon,* shown running at full speed in pursuit of its prey, the antelopelike *Ramoceros;* a twelve-million-year-old early horse, *Protohippus*, which may have died trying to give birth; and a *Palaeocastor*, an early relative of beavers, shown where it was found at the bottom of an eight-foot-long spiral burrow.

Three Charles R. Knight murals and dozens of his smaller paintings have been restored and are displayed in the fossil mammal halls. In addition, for each of six extinct species, contemporary artist Jay Matternes has contributed three drawings depicting the fossil skeleton, the muscles and tendons, and how the animal might have looked in life. At interactive computer stations, visitors may take tours of evolutionary history with Museum scientists and see reconstructions of the fossil animals in their original habitats.

The new fossil mammal halls and the Museum's new library are part of a vast renovation plan still in progress. Two new dinosaur halls on the fourth floor will open in 1995. The project will be finished in 1996 with the opening of the Hall of Primitive Vertebrates and an Orientation Center.

Martyn Colbeck's prize-winning photograph
© British Gas Wildlife Photographer of the Year Competition

The Biodiversity Crisis

The last three lectures in a series sponsored by the Museum's Center for Biodiversity and Conservation will be held this month. On Tuesday, May 3, and Thursday, May 12, Joel L. Cracraft, a curator in the Department of Ornithology and acting director of the Center, will discuss the scientific basis of current mass extinctions in the earth's species. On Tuesday, May 17, Michael J. Novacek, a Museum vice-president and dean of science, will talk about the challenges in dealing with the biodiversity crisis and the relationship of science to public policy. The lectures begin at 7:00 P.M. Call (212) 769-5310 for information.

Conservation in the Twenty-first Century

Richard Leakey, paleontologist and director of Kenya's Wildlife Service, will talk about environmental dangers that threaten us with extinction. He will draw upon material from his new book, *Origins Reconsidered: In Search of What Makes Us Human.* The talk will be given on Wednesday, May 18, at 7:00 P.M. in the Main Auditorium. Tickets are $29 ($19 for Museum and Learning Annex members). Call (212) 769-5310 for information.

Thar' She Blows

Kenneth A. Chambers, a retired Museum educator and lecturer in zoology and exploration, will discuss the turbulent history of whaling in a slide-illustrated talk on Tuesday, May 3, at 7:00 P.M. in the Kaufmann Theater. Tickets are $15. For additional information, call (212) 769-5310.

Asian and Pacific-American Celebration

This month, Asian and Pacific-American cultures are the focus of the Education Department's year-long series on cultural diversity. On Sunday, May 22, choreographer Yoshiko Chuma and the School of Hard Knocks will present *A Night at the Millionaire's Club,* a contemporary work based on traditional Japanese concepts of space and time. On Sunday, May 29, the Pan-Asian Repertory Theatre will present scenes from *Wilderness,* the final play in a trilogy by Chinese playwright Cao Yu. The programs, at 2:00 and 4:00 P.M. in the Kaufmann Theater, are free with admission to the Museum. For a complete brochure of events, call (212) 769-5315.

An Upcoming Eclipse and a Comet Collision

Weather permitting, the solar eclipse on Tuesday, May 10, can be observed safely through telescopes at the Planetarium. On Thursday, May 5, meteorologist Joe Rao will give a slide-illustrated lecture about this upcoming eclipse. In late July, Comet Shoemaker-Levy 9 is due to hit Jupiter. David Levy, a scientist at the Lunar and Planetary Laboratory of the University of Arizona and codiscoverer of the comet, will talk about the comet's collision course on Monday, May 23. Both talks will begin at 7:30 P.M. in the Sky Theater. For tickets and information about all Planetarium events, call (212) 769-5900.

Restoration of the Knight Murals

Charles R. Knight was one of the first painters to re-create prehistoric animals based on the study of fossils. In 1911, the Museum commissioned him to create a series of murals that portrayed saber-toothed cats, giant beavers, mammoths, mastodons, and other extinct creatures. The restoration of these murals, under the direction of paintings conservator Felicity Campbell, will be the subject of a talk on Friday, May 6, in the Kaufmann Theater at 7:00 P.M. Call (212) 769-5606 for information.

Photographer of the Year Exhibition

A closeup of an elephant taking a dust bath won British photographer Martyn Colbeck first place in the British Gas Wildlife Photographer of the Year Competition. Organized by *BBC Wildlife* magazine and the Museum of Natural History in London, the competition is in its tenth year, and includes 11,500 entries from forty-two countries. Thirty-nine winning photographs will be exhibited in the Akeley Gallery from Friday, May 20, to Sunday, July 31.

These events take place at the American Museum of Natural History, Central Park West at 79th Street in New York City. The Kaufmann Theater is located in the Charles A. Dana Education Wing. The Museum has a pay-what-you-wish admission policy. For more information about the Museum, call (212) 769-5100.

TECHNOLOGY UPDATE

500 miles from nowhere, it'll give you a cold drink or a warm burger...

NASA space flights inspired this portable fridge that outperforms conventional fridges, replaces the ice chest and alternates as a food warmer.

By Charles Anton

Recognize the ice cooler in this picture? Surprisingly enough, there isn't one. What you see instead is a Koolatron, an invention that replaces the traditional ice cooler, and its many limitations, with a technology even more sophisticated than your home fridge. And far better suited to travel.

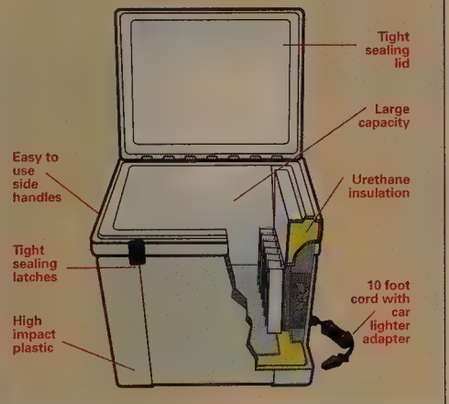
What's more, the innocent looking box before you is not only a refrigerator, it's also a food warmer.

NASA inspired portable refrigerator. Because of space travel's tough demands, scientists had to find something more dependable and less bulky than traditional refrigeration coils and compressors. Their research led them to discover a miraculous solid state component called the thermo-electric module.

Aside from a small fan, this electronic fridge has no moving parts to wear out or break down. It's not affected by tilting, jarring or vibration (situations that cause home fridges to fail). The governing module, no bigger than a matchbook, actually delivers the cooling power of a 10 pound block of ice.

The refrigerator from outer space.

The secret of the Koolatron Cooler/Warmer is a miniature thermo-electric module that effectively replaces bulky piping coils, loud motors and compressors used in conventional refrigeration units. In the cool mode, the Koolatron reduces the outside temperature by 40 degrees F. At the switch of a plug, it becomes a food warmer, going up to 125 degrees.



From satellites to station wagons. Thermo-electric temperature control has now been proven with more than 25 years of use in some of the most rigorous space and laboratory applications. And Koolatron is the first manufacturer to make this technology available to families, fishermen, boaters, campers and hunters– in fact anyone on the move.

Home refrigeration has come a long way since the days of the ice box and the block of ice. But when we travel, we go back to the sloppy ice cooler with its soggy and sometimes spoiled food. No more! Now for the price of a good cooler and one or two seasons of buying ice, (or about five family restaurant meals), all the advantages of home cooling are available for you electronically and conveniently.

Think about your last trip. You just got away nicely on your long-awaited vacation. You're cruising comfortably in your car along a busy interstate with only a few rest stops or restaurants. You guessed it... the kids want to stop for a snack. But your Koolatron is stocked with fruit, sandwiches, cold drinks, fried chicken... fresh and cold. Everybody helps themselves and you have saved valuable vacation time and another expensive restaurant bill.

Hot or cold. With the switch of a plug, the Koolatron becomes a food warmer for a casserole, burger or baby's bottle. It can go up to 125 degrees.

And because there are no temperamental compressors or gasses, the Koolatron works perfectly under all circumstances, even upside down. Empty, the large model weighs only 12 pounds and the smaller one weighs just seven. Full, the large model holds up to 40 12-oz. cans and the smaller one holds six.

Just load it up and plug it in. On motor trips, plug your Koolatron into your cigarette lighter; it will use less power than a tail light. If you decide to carry it to a picnic place or a fishing hole, the Koolatron will hold its cooling capacity for 24 hours. If you leave it plugged into your battery with the engine off, it consumes only three amps of power.

Limited time offer. Because Comtrad is bringing this offer to you directly, you save the cost of middlemen and retail mark-ups. For a limited time only, you can get this advanced, portable Koolatron refrigerator at the introductory price of $99. Call today to take advantage of this special promotional pricing. Most orders are processed within 72 hours.

The versatile Koolatron is available in two sizes. The P24A holds 30 quarts and the smaller P9 holds seven quarts. An optional AC adaptor lets you use them in your rec room, patio or motel room. They plug into any regular outlet.

Try it risk free. We guarantee your satisfaction with any product from Comtrad Industries. With the Koolatron you get our complete "No Questions Asked" 30 day money-back guarantee. Plus you get a full one year manufacturer's limited warranty. If you are not satisfied for any reason, just return the product for a complete refund.

Koolatron (P24A) holds 30 quarts	**$99**	$12 S&H
Koolatron (P9) holds 7 quarts	**$79**	$8 S&H
Optional AC Adapter (AC 10)	**$39**	$6 S&H

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Four Giants of Paleontology

by Edwin H. Colbert

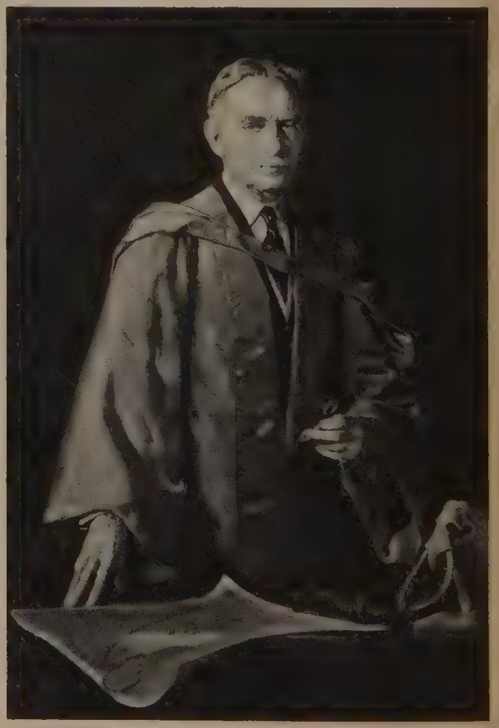
In 1859, the year that *The Origin of Species,* by Charles Darwin, appeared, changing forever the way in which we think about ourselves, our origins, and our world, Henry Fairfield Osborn was just two years of age. This son of wealthy and loving parents, who was supposed to become an influential figure in the world of railroads and high finance (or so his father thought), was destined to become instead a leading authority on the evolution of backboned animals.

For many years Osborn was a dean and professor of zoology at Columbia University and, simultaneously, a prime driving force in the growth of an institution that has been at the forefront of evolutionary studies since the 1880s—the American Museum of Natural History. Osborn was appointed president of the Museum in 1908 and served for twenty-five years.

In 1871, twelve years after Darwin's epochal publication, William Diller Matthew was born in Saint John, New Brunswick. Later, as a young man, Matthew gravitated to Columbia, where he came under the influence of Osborn, then presiding over the Department of Zoology. Osborn's passion for the study of vertebrate evolution was contagious. So at the age of twenty-four, Matthew, who had come to Columbia seeking a career in mining geology, headed instead for a paleontologist's life at the American Museum as a colleague of Osborn's.

Seventeen years after that fateful year of 1859, William King Gregory was born in Greenwich Village, New York City. Eventually he also attended Columbia. In 1899 he became Osborn's assistant, thereby initiating his own long and distinguished career at Columbia and at the American Museum, where he was one of those rare individuals on the curatorial staff—a native New Yorker.

For more than three decades the three men—the mentor and his two students—worked together at the Museum cataloging and trying to make sense of its rapidly expanding collection of fossil vertebrates. Each year, the Museum's famous bone collectors, such as Barnum Brown, would bring in thousands of specimens, newly freed from tons of rock. Osborn was interested in extinct reptiles and mammals, particularly mammals. Matthew was an internationally respected authority on mammalian evolution, and Gregory was



Henry Fairfield Osborn
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On May 14, 1994, the American Museum of Natural History launches its 125th-anniversary celebration by opening the LILA ACHESON WALLACE WING OF MAMMALS AND THEIR EXTINCT RELATIVES. Mastodonts, giant ground sloths, and other mammalian fossils from the Museum's collection will be on view.

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justly famous for his encyclopedic knowledge of all the vertebrates.

These three quite naturally developed different approaches to their evolutionary studies. Osborn was by training a biologist, so his interpretation of the evolution of extinct animals was dominated by his knowledge of related modern animals. In contrast, Matthew's view of evolution, particularly mammalian evolution, was based upon his broad background in geology and especially stratigraphy—the sequence of rock strata in which fossils are found. (Matthew's father, George Frederic Matthew, was a distinguished Canadian geologist, and young Matthew became further steeped in geology under another Columbia mentor, James Furman Kemp.) Gregory was primarily a comparative anatomist who extended his comparisons to vertebrates of all geologic ages. His scholarship was indeed comprehensive, for his view of the world reached across time, space, and phylogeny.

The three men—Osborn, Matthew, and Gregory—brought to the enormously complex subject of vertebrate evolution a powerful combination of different talents and outlooks that helped shape the discipline for decades to come.

They worked both separately and together, and their collaborative studies describing previously unknown fossil species led to the revelation of many new evolutionary facts. Important assemblages of extinct creatures were worked up for publication under the joint authorships of Osborn and Matthew, Osborn and Gregory, and Matthew and Gregory. As for their individual interpretations of evolutionary processes, most of those papers were signed singly because of their separate and sometimes divergent opinions.

Osborn, a large and forceful man, liked to formulate evolutionary "laws" to which he appended his own designations. Per-

haps he fancied himself as a sort of evolutionary Jove, issuing edicts for the guidance of his followers. In his later years, Osborn became remarkably pompous and vain—a result of having occupied high positions in the scientific world, as well as in the social milieu of New York. But as Gregory pointed out, "Osborn himself was under no delusion as to the lack of enthusiasm with which his writings on the theory of evolution were received in many quarters." Osborn had a strong predilection for the concept of orthogenesis—the idea that organisms evolved inexorably in determined directions, like soldiers marching toward a defined objective. Furthermore, Osborn became obsessed with the idea of evolutionary parallelism—for him, animals separated at very early stages in their histories to evolve side by side along discrete, but similar, lines.

Osborn's view of evolution through time is nicely exemplified in his huge, two-volume monograph on the proboscideans (the mastodonts and elephants) in which the lines of all families are traced back to presumably ancient, unknown origins, and nothing seems to be ancestral to anything else. This concept of straight-line evolution prevailed in his earlier works, including his researches on fossil horses.

A similar story is seen in Osborn's studies of human evolution—in this case with Gregory doing much of the detailed research. In the end, Osborn wished to carry the origins of mankind far back in time, beyond anything justified by geologic evidence. Gregory claimed Osborn was "afflicted with pithecophobia—the dread of apes as relatives or ancestors." Although their views became irreconcilably divergent over this issue, they remained friends.

Despite several of his stubbornly held premises in approaching the material, Osborn made many outstanding contributions to vertebrate evolution, notably his work on the basic evolutionary relationships of reptiles, on the origin of mammals from mammallike reptiles, on the origins of mammalian molar teeth, and on the evolutionary histories of the perissodactyls, or odd-toed hoofed mammals—the titanotheres, rhinoceroses, and horses. While writing his massive monograph on the elephants, Osborn liked to revise his drafts *after* the work was set in type.

A personality such as Osborn's—overbearing, pompous, and vain—is apt to collide with the real world now and then. Once Osborn, accompanied by Fred Smythe, of the Museum's finance office, went to City Hall in New York, to see

William Diller Matthew
AMNH

Joseph McKee, president of the Borough of Manhattan. Osborn announced to the receptionist that "President Osborn is here to see Mr. McKee." Soon a flunky appeared to inform the visitors (much to the delight of Smythe) that "President McKee will now see Mr. Osborn."

Osborn was a typologist and a "splitter"; he thought that comparisons among specimens should be taken right back to the types on which the original descriptions of species were made. Matthew, allowing for variation within species, was a "lumper," who viewed population samples as a truer basis for determining species relationships. These divergent approaches, together with Osborn's orthogenetic ("straight line") concept of evolution, led to the abandonment by Matthew of their joint authorship of a massive monograph on fossil horses to which Matthew had devoted many years of research.

Far from being overpoweringly forceful in the Osbornian sense, Matthew was none the less a man of solid convictions, based upon the facts as he saw them in the fossil record. As Gregory wrote of his longtime friend,

> It may be said in brief that Evolution was the one theme about which he was always writing.... He never wearied of insisting upon the value of facts as compared with theories.... Scrupulous intellectual honesty was one of his outstanding characteristics.

Matthew was a firm believer in the close relationship between environments and the evolution of animals, a belief that found expression in his 1915 publication *Climate and Evolution*. This work, a milestone in Matthew's evolutionary studies, attracted universal attention and has been a point of reference, and a subject of debate, during the many years since its publication.

One of his first projects at the American Museum was a comprehensive synthesis of the Cenozoic strata in North America within which fossil mammals are to be found. With his background of geologic knowledge, Matthew saw the evolution of horses, for example, differently than did Osborn. Realizing that primitive horses were closely related to primitive rhinoceroses and tapirs, all of which are found within strata of the Eocene age (some fifty million years ago), Matthew studied the Cenozoic mammals as they were spread out in space, as well as over time. He was as concerned with the worldwide distribution of mammalian faunas as he was with the lines of descent of particular species.

Consequently much of Matthew's research was based upon the geologic formations of the western United States, with which he became thoroughly acquainted during successive seasons of fieldwork. His analysis of the fossils resulted in his early great monograph on the ancient carnivorous and insectivorous mammals of the Bridger Basin of Wyoming. His crowning work—a huge monograph on primitive mammals from the Paleocene strata of the San Juan Basin of New Mexico—was also based on assiduous fieldwork as well as Museum study.

Matthew was a witty person, who reveled in the world's absurdities. He was a great versifier, and wrote many ditties for the amusement of his colleagues, such as:

DARWINIAN THOUGHTS ON VIEWING A SKELETON OF ERYOPS

From Palaeozoic slime he rose,
Your ancestor and mine,
With webby toes,
Retroussé nose
And, I suppose, a lateral line.

Gregory's characterization of Matthew as a man of "scrupulous intellectual honesty" could well be applied to Gregory himself. Although he was an assistant to Osborn for many years, and although in 1910 he took over Osborn's position as professor at Columbia (in addition to his curatorial duties at the Museum), he did not submit to Osborn's overwhelming personality. He expressed his own opinions, particularly with regard to evolution, but he had the knack of doing so in a way that did not ruffle the Osbornian feathers. He would address a memo to Osborn "to our

own imperial mammoth" or "to our great sulphur-bottomed whale," and Osborn loved it. Even in later years, when the two had their fundamental disagreements about the evolution of humankind, Osborn harbored no hostility toward Gregory. The same could not be said about the Osborn–Matthew relationship, however.

Gregory was a gentle and in many respects an unworldly soul. Aside from his anatomical studies, he never worked with his hands. I cannot picture him, for instance, using a hammer, saw, or screwdriver to fashion some useful object for his study. One day he was coming back to the American Museum from lunch (he lived nearby) thinking his thoughts, when suddenly he stumbled into a coal-hole in the sidewalk. Such apertures for delivering coal to the brownstone houses were common features on the old slate sidewalks of Manhattan. In this instance the workmen, after having delivered a load of coal, had failed to put the heavy cast iron cover back in place. Gregory scrambled out of the hole a bit soiled, and indignantly rang the doorbell of the nearby dwelling, planning to give the owner what for. But when a sweet old lady came to the door, Gregory forgot his wrath and wound up the situation by manfully replacing the dusty iron cover with his own hands.

In addition to his detailed, comprehensive knowledge of all the land vertebrates, or backboned animals, Gregory was a universally recognized authority on the evolution of fishes. He knew not only the primitive fishes as seen in the fossil record but also the myriad modern bony fishes. He was an authority on the mammallike reptiles, so abundantly represented in the fossil record of South Africa, as well as on the evolution and relationships of marsu-

William King Gregory
AMNH

pials, the pouched mammals so abundant in Australia's modern fauna. He had also devoted many years of research to the evolution of the primates, including humans, and his book *The Origin and Evolution of the Human Dentition* remains a classic. Alfred Sherwood Romer, one of Gregory's students who became a leading vertebrate paleontologist, once remarked to me that in his opinion, no one on earth had such intimate knowledge of the vertebrate skull as did William King Gregory.

In 1927 Matthew moved to California to assume the chairmanship of the Department of Paleontology at the University of California at Berkeley. His chosen successor at the American Museum was George Gaylord Simpson, born in 1902, who had recently earned his doctorate from Yale and who had spent a postdoctoral year at the British Museum (Natural History) in London. He was a worthy successor to Matthew, who by 1927 had established a towering reputation as a student of mammalian evolution. Paleontologist Stephen Jay Gould has written that "George Gaylord Simpson, in the impact of his ideas and by the power of his writing, both in style and substance, was the most important paleontologist since Georges Cuvier." This is not excessive praise; the man was a paleontological genius. One of Shakespeare's Elizabethan contemporaries said of the bard, "his mind and hand went together; and what he thought, he uttered with that easiness, that we scarce received from him a blot in his papers." So it was with Simpson; the massive output of his papers, monographs, and books began as flowing handwritten manuscripts, with scarcely a rewrite on their pages.

A small and unprepossessing figure, Simpson was not easy to know. On the surface, he was shy; underneath he was determined, even belligerent, as befits a person who is in complete command of his field. During the Second World War, Simpson was attached to Gen. George Patton's staff as a major. One day an order came down from the imperious general for Major Simpson to shave off his beard immediately. Simpson sent his respects and firmly pointed out that as long as he could get a gas mask on over his beard, there was no regulation that required him to shave. The general may have fumed in private, but Simpson kept his beard.

His work focused on the study and elucidation of mammalian evolution along the lines that Matthew had followed. Thus, Simpson was very much involved with extinct mammalian faunas, with their evolutionary relationships, and with the distributions of mammals through geologic time. He was, like Matthew, essentially a geologic paleontologist, but with a strong biological understanding of the fossils to which he devoted his attention.

Also like Matthew, he was a firm believer in the permanence of the continents. After the Second World War, however, when the geologic evidence for plate tectonics (the "drifting" of continents through time) became overwhelming, he finally gave in, but with great reluctance. He will be best remembered for his beautifully written and closely argued books, such as *The Meaning of Evolution, Tempo and Mode in Evolution,* and *The Major Features of Evolution.* Also of enduring interest is a book he wrote early in his career, *Attending Marvels,* a superb account of his first expedition to Patagonia, the land where Darwin himself had excavated fossils of a giant ground sloth.

Simpson was a leader, along with Ernst Mayr (who was for many years at the American Museum and is now at Harvard), in the movement known as evolutionary synthesis. During the late 1940s, this new interpretation of Darwinism attempted to combine the findings of modern paleontology, systematics, animal behavior, and population genetics into an integrated, or "synthetic," discipline.

Although he was a deeply contemplative thinker and a superb theorist, Simpson did not dwell in an ivory tower. He was very much a field man who spent many seasons in the fossiliferous badlands of North and South America, collecting the

George Gaylord Simpson
AMNH

fossils on which he based his descriptive research and his paleontological conclusions. Afterward, he spent untold hours in the laboratory, carefully studying the fossils that he and other paleontologists had collected.

Like Osborn and Matthew, Simpson wrote about the evolution of horses. But in contrast to Osborn's sweeping and relatively simple (unilineal) view of equid evolution, he delineated a complex history that involved several evolutionary lines, progressing from woodland browsers to high-plains grazers. As Simpson put it, "Evolution doesn't move in straight lines, but the minds of some scientists do." In developing these studies, he was in many respects following the path that Matthew had taken some decades earlier.

Two lines of research by Simpson deserve particular mention. One was exemplified in his two thorough monographs about all the Mesozoic mammals known at the time he was entering upon his remarkable paleontological career. His other research was his detailed study of the classification of all mammals—both living and extinct—a long-term project that established him as an authority on the rather legalistic subject of animal taxonomy.

Most of his scientific career was spent at the American Museum, but in 1959 he moved to Harvard. His final years were spent in Tucson, Arizona, where he was associated with the University of Arizona.

Today the study of organic evolution at the American Museum of Natural History is in its second century of research and the four men are now historical figures. The contemporary effort, involving modern, expanded techniques at paleontological sites around the world and modern sophisticated studies in the laboratory, is a projection of the seminal research by Osborn, Matthew, Gregory, and Simpson, who through three-quarters of a century established the Museum as a world center for evolutionary fact and theory. Theirs were lasting contributions to our knowledge of the history of life.

Edwin H. Colbert, for many years chairman of the American Museum's Department of Vertebrate Paleontology, knew and worked with the great paleontologists he writes about. (He began his career in 1930 as an assistant to Henry Fairfield Osborn.) Now curator of vertebrate paleontology at the Museum of Northern Arizona, he lives in Flagstaff with his wife, Margaret—the daughter of paleontologist William Diller Matthew.

Bonaventure Island, Quebec

by Robert H. Mohlenbrock

Flat-topped, sheer-sided Percé Rock protrudes into the Gulf of Saint Lawrence on the eastern edge of Quebec's Gaspé Peninsula. During high tide, it stands isolated from the mainland, but at low tide, one can reach it by walking across a 400-yard stretch of exposed, slippery rocks. Looming out of the water three miles east of Percé Rock is another landmass. This is Bonaventure Island, internationally known for its colony of nesting gannets.

Percé Rock lies off the eastern shore of the Gaspé Peninsula. Above, right: A gannet uses seaweed to build its nest on Bonaventure Island.

Victoria Hurst; First Light

Along with Percé Rock, it was designated a provincial conservation park in 1985 under the management of the Quebec Department of Recreation, Game, and Fish.

According to geologist H. W. McGerrigle, Percé Rock consists of layers of limestone deposited by the sea about 375 million years ago. Its seaward side ends in a low, wide arch that creates a huge window through the rock. Two hundred feet beyond is a separate pillar of rock, or "seastack." This pillar was also once connected to Percé Rock by an arch, but the arch collapsed in 1845. According to sailors' reports from about 1600, there once was a series of four arches. The one that remains should last a few hundred more years, according to McGerrigle.

Bonaventure Island is reached by ferry from the village of Percé, nestled beneath nearby mainland cliffs. Because of the severe winters and persistence of ice in the gulf long into spring, the ferry operates only from mid-June to mid-September. Traveling there in August, I was fortunate to visit Bonaventure Island accompanied by naturalist Lucie Lagueux, author of a popular booklet about the gannets. In a half-hour ride, the ferry crossed the three miles of open water from the mainland and then slowly circled the island in a clockwise direction before docking on the west side, facing Percé.

As the ferry passed the cliffs on the north and northeast sides of the island, countless seabirds filled the air above and in front of the rock. Most were gannets out for their morning fishing expedition, but we also saw black-legged kittiwakes, black guillemots, double-breasted cormorants, great black-backed gulls, herring gulls, razorbills, and common murres. A very small colony of common puffins also nests on the island, but we saw none on the day I was there. From the ferry we could see that every possible surface on the island's upper rocky terraces was covered by white, nesting birds. Lucie Lagueux estimated that there were about 21,000 gannet pairs, roughly 20 percent of the known world population of this species.

The ferry docks on the western side of the island, where the slope to the water is gentle enough for passengers to disembark. A fishing community was established here during the seventeenth century. A few abandoned buildings and other evidence of this settlement remain. Most of

Gerry Ellis

the area around the landing site has been cleared, and the vegetation consists of weedy plants introduced through human disturbance—milfoil, wild parsnip, burdock, vetch, and timothy grass.

All around the island is a narrow strip of open, rocky terrain with primarily arctic flora, known locally as the natural prairie. Most likely, these arctic species were driven southward during the last Ice Age and were left behind after the glaciers receded, about 10,000 years ago. They include a tiny whitlow grass mustard, three-toothed cinquefoil, the live-forever saxifrage, bistort, and a wild iris. While most of the island is covered by a boreal coniferous forest, the natural prairie survives because it is undisturbed and because there is not enough soil for forest trees to gain a foothold.

Several trails lead from the dock up through the moist, cathedrallike forest to the north-facing cliffs where the gannets nest. Balsam fir and white spruce are the dominant conifers, and they grow so densely that sunlight rarely reaches the moss-covered forest floor. Many kinds of wildflowers, all adapted to living in a poorly lighted and very moist environment, grow up through the carpet of mosses. Among them are goldthread, purple wood sorrel, twinflower, one-flowered wintergreen, bunchberry, and lady-slipper. Most have green leaves and use the sun's energy in photosynthesis. Some of the plants, however, such as Indian pipe and coralroot orchid, lack chlorophyll and live entirely off the rich organic matter that accumulates on the forest floor.

As we climbed the trail upward through the firs and spruces, the great commotion of nesting gannets became louder and louder. Suddenly the forest ended, and we were standing on a fifty-foot-wide grassy strip that was all that separated us from the rocky terrace at the edge of the cliff. On this terrace were the most birds I had ever seen in one place, with scarcely any rock

Bonaventure Island
For visitor information write:
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Quebec Department of Recreation,
Game, and Fish
C. P. 310, Percé, Quebec G0C 2L0 Canada
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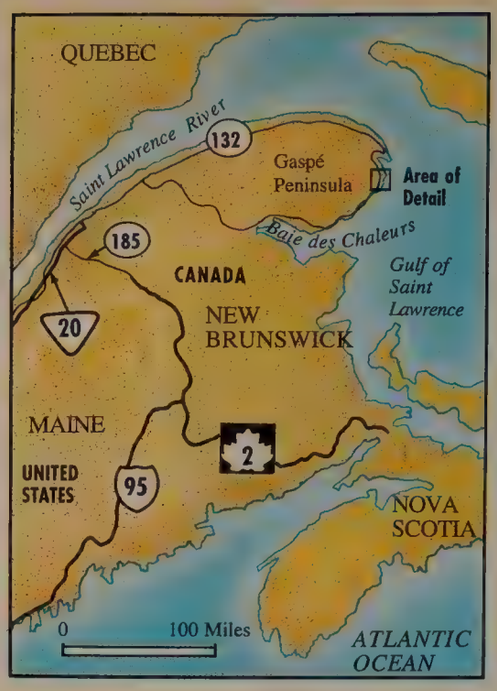
Joe LeMonnier



showing between adjacent nests. The park service permits visitors to come to a fence not more than six feet from the nearest nesting birds. There is also a sturdy, forty-foot-tall observation platform that provides an overall view of the spectacle.

Gannets are large, soft-looking birds with dark bills and legs. A patch of yellow-brown on the back of the head is all that marks the otherwise white, downy plumage. An adult gannet weighs about seven pounds. When spread, its wings span a little more than five feet. The birds I saw nesting were at least five or six years old, the age of sexual maturity for a gannet. Younger gannets congregate on the rocks at the base of the cliffs, practicing their diving and fishing skills and learning the techniques of social behavior that they will need when they are sexually mature.

The adults, which pair for life, arrive in early April from their wintering grounds in Florida and Mexico. They soon begin building their nests of grass on the bare rock. Each site is about twenty-nine and a half inches in diameter, separated from adjacent nests by no more than two inches. Mid-April is the mating season, and it begins with the art of fencing, in which a male and female carry out a ritual of crossing beaks.

The female lays a single white egg in early May, and incubation lasts for forty-three days, with the female and the male alternating shifts every thirty to thirty-six hours. When the parent that is incubating the egg wants to leave the nest, it signals its partner to return by pointing its beak straight up.

The egg hatches about the third week in June. The hatchling is black, naked, and blind, but within three weeks, it weighs two-thirds as much as the adult. At seven weeks, the chick actually outweighs the adult by two pounds. After exercising its wings, it takes its first flight from the cliff, landing in the sea. This action is so exhausting, and the young bird is so heavy, that it is unable to take off again for a few days. Instead, it swims away from the island, surviving on its excess fat and some fish. During this time some 60 percent of the fledglings perish.

Young gannets that survive the fledgling stage usually start on their migration south in September, before stormy weather sets in. Adults stay longer, feeding on the abundant fish and perhaps lingering over the late-hatching chicks (most of which are doomed to perish). The adults begin the long journey southward about the middle of October, and the last ones are gone a few weeks later. Interestingly, the adults leave Bonaventure Island as pairs, but the males overwinter on the Gulf Coast of Mexico, while the females generally go to the Atlantic coast of Florida.

The gannets' breeding cycle meshes with the seasonal distribution of the fish on which the birds feed. Gannets arrive at Bonaventure Island in the spring, precisely when large numbers of herring are spawning in the nearby waters. The hatching of the gannet eggs coincides with the spawning of another fish, the capulin. Adult gannets feed upon the capulin, then regurgitate some of the food for their young. They continue by feeding them on mackerel, which subsequently appear in abundance. Then, just as the young are fledging, a second large population of herring arrives.

During the late 1960s, the hatching success rate for gannets, normally 75 percent, fell to half that. Scientists from the Canadian Wildlife Service discovered that DDT, ingested by birds from contaminated fish, was being stored in the bird's fat and ultimately causing a calcium deficiency in the eggshells. Thus weakened, many of the shells would break. When DDT was eventually eliminated, the hatching rate returned to normal. Nonetheless, the large gannet colony at Bonaventure Island must always be monitored for oil spills, PCB contamination, and other environmental pollutants. A major disaster here could wipe out up to one-fifth of the birds' total population.

This month, Robert H. Mohlenbrock, professor emeritus of plant biology at Southern Illinois University, Carbondale, takes a northern holiday from his usual beat, the 156 U.S. national forests.

Unlike most flowering plants, Indian pipe lacks green leaves for photosynthesis.
Thomas A. Schneider

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Ring of Fire

by Gail S. Cleere

A total solar eclipse is perhaps the most spectacular celestial event, but unfortunately, at any given location, it is very rare: the next one visible in the continental United States will occur on August 21, 2017. (In all of recorded history, the sun has never been totally eclipsed over Washington, D.C., where I write.) On May 10, however, the next best thing, an annular solar eclipse, will occur as the moon passes in front of the sun without completely covering it. The result will be a brilliant ring of sunlight surrounding the black disk of the moon. Starting in the Pacific Ocean, south of the Hawaiian Islands, the annularity will be visible along a 150-mile-wide swath, extending across the United States, from New Mexico to Maine, before it crosses the Atlantic and ends in Morocco.

Solar eclipses can occur only during the new moon, the only time of the month that the moon and the sun are in the same part of the sky. Solar eclipses do not occur every month because the orbits of the earth, moon, and sun are not in the same plane. The moon's orbit is tilted by 5° in relation to the earth's orbit around the sun, so during the new moon phase, the moon is usually slightly above or below the sun. Only rarely does it pass directly in front of the sun. A minimum of two solar eclipses (total, annular, or partial) occur every year; the maximum is five.

A further complication is that the moon's orbit is not perfectly round. When the moon is near perigee, its closest distance to the earth, its disk is just large enough to cover the entire sun. (By coinci-

The times given represent the moment of maximum eclipse and are shown in eastern daylight time (adjust for local time).

dence, the sun is 400 times farther away from us than the moon, but it is also 400 times larger than the moon, so that in the sky the two appear to have roughly the same diameter. This is what makes solar eclipses so spectacular.) During apogee, however, when the moon is farthest from us, its disk is not large enough to cover the sun completely, so a ring, or annulus, of sunlight escapes around the edges. Along one side, the ring is often broken up into bright points of light by mountains on the moon's surface.

During May's annular eclipse, the moon's disk will cover 88 percent of the sun. Even 12 percent of sunshine in the ring of annularity is still a lot of light, however, and although the sky will become darker, it won't be spectacularly so. At the height of the eclipse, the lighting will be equivalent to that of a heavily overcast day. What will be striking is that the edges of shadows will get sharper (because light is coming from a smaller source), and hundreds of pinhole images of the sun will be seen under trees as the image of the sun is filtered through the leaves.

This effect can be simulated by making a pinhole in a card and projecting the image of the sun through it onto a sheet of paper. This method is one way of viewing eclipses safely. To look at the sun during eclipses, you need special filters to protect your eyes from its direct rays, which can quickly cause permanent damage. Because all the bright photosphere of the sun is hidden by the moon in a total solar eclipse, during totality, observers can safely look directly at the eclipse with the naked eye. Annular and partial eclipses, however, can never be viewed safely because some of the solar surface remains exposed. If you must look directly at the sun, use a rectangular welder's glass of shade number 14, which can be purchased at hardware stores and welding supply firms. Welder's glass of lower shade numbers are not safe for solar viewing. Nor do gelatin filters, color film, photographic filters, smoked glass, or sunglasses offer any protection.

Viewers near the center of the eclipse path will see a symmetrical ring of sunlight around the moon, while those near the edges of the track will see the moon off center in the solar disk. At its best near Toledo, Ohio, the annular phase of the eclipse will last six minutes and thirteen seconds. The rest of the United States, as well as Canada, Mexico, Central America, Greenland, Iceland, the Arctic, and portions of Europe and Africa, will witness a

partial solar eclipse. In Hawaii, the sun will rise partially eclipsed. For most of Europe, the sun will set eclipsed.

THE PLANETS IN MAY

Mercury is in the evening skies during the second half of the month and is in a good position for Northern Hemisphere observers just after sunset. On the 15th, Mercury is 8° above the red star Aldebaran in Taurus. On the 30th, Mercury reaches its greatest distance east of the sun for the year—a whopping 23° east of the sun. Now is the time to look for Mercury in the western twilight.

Venus shines at –3.9 magnitude just after sunset in the west. On the 4th, it will pass 6° north of the reddish star Aldebaran. On the 12th and 13th, look for Venus just above the very young moon. Those lucky enough to be in the path of annularity during the eclipse on the 10th should look for Venus about 30° to the left (east) of the sun as the sky darkens.

Mars remains difficult to spot, low in the southeast as the sun rises. On the 7th and 8th the waning moon passes nearby.

Jupiter continues to dominate the night sky. It rises a couple of hours before sunset in the southeast and travels across the southern sky, setting just before sunrise. On the nights of the 22d and 23d, the gibbous moon passes near Jupiter. All month long Jupiter vies for our attention with the bright star Spica, which is nearby in the constellation Virgo.

Saturn rises in the east several hours before sunrise. The planet is in the constellation Aquarius. Look in Pisces for the bright star Fomalhaut—from the Arabic, meaning "the fish's mouth"—just below Saturn, nearly matching the ringed planet in magnitude. On the 5th, look for Saturn near the waning crescent moon in the predawn skies.

Uranus and **Neptune** remain in eastern Sagittarius. Both are now in their apparent westward motion through the constellation—a function of the earth overtaking them in orbital speed (all the planets move in an easterly direction through the constellations in the sky). In dark, predawn skies, both planets can be found with binoculars and a detailed sky chart, just east of the dense river of stars forming the Milky Way. Facing Uranus and Neptune, you are looking toward the center of the galaxy.

Pluto's biggest day of the year occurs this month, at opposition in our nighttime skies on the 17th in Libra. It is as far from the sun as it can get for the year, so this is the best time for serious astronomers to try observing Pluto—the faintest planet in the solar system.

The **Moon** reaches last quarter on the 2d at 10:32 A.M., EDT; is new on the 10th at 1:07 P.M., EDT; and reaches first quarter at 8:50 A.M., EDT, on the 18th. The moon is full on the 24th at 11:39 P.M., EDT, and will produce the second eclipse of the month. This partial lunar eclipse begins at 10:38 P.M., EDT, when the moon enters the dark umbral shadow of the earth. Maximum eclipse will come at 11:30 P.M., EDT, when the lower quarter of the moon's disk is covered. The moon will leave the umbra at 12:23 A.M., EDT.

The Eta Aquarid meteors, a stream of frozen particles left behind in the path of Halley's comet, are best during the hours just after midnight on May 5. Unfortunately, moonlight will interfere. They are named not for the comet but for the place in the sky where they seem to originate (a dim star in the faint constellation Aquarius). We can expect to see twenty bright meteors per hour: some bright yellow; some leaving long, glowing trails. These meteors were first recorded by the Chinese in A.D. 401.

Gail S. Cleere lives in Washington, D.C., and writes on popular astronomy.

Old Foods in the New World

by John R. Alden

Until a decade or so ago, no one thought about ancient societies as having cuisines. Cuisines were high culture, like haute couture and symphony orchestras. France had a cuisine; so did China. But that was about it. In the United States people lived on food like barbecue, baked beans, and corn on the cob, and certainly none of that qualified as cuisine. As for the ancient world, most of us figured those folks were just happy to have a mess of pottage.

Our perceptions have changed. Cuisines no longer follow formal repertoires of ingredients, recipes, and techniques. They are simply coherent styles of selecting, preparing, flavoring, presenting, and consuming food, and every culture, region, social stratum, and ethnic group is recognized as having a cuisine of its own. Fast-food is an element of modern American cuisine; so are corn flakes and, in parts of the country, corn dogs. Futhermore, ancient societies had cuisines too.

America's First Cuisines describes what three of the New World's most important aboriginal societies—the Aztecs, the Maya, and the Inca—ate and how they went about eating it. Sophie Coe, an anthropologist and food historian specializing in Latin America, chose these groups for two practical reasons. First, of all the New World's disparate cultures, these three made the greatest contribution to the cornucopia spilling from the shelves of today's supermarkets and filling the pages of today's cookbooks and restaurant menus. Second, says Coe, "that is where the information is." These societies are simply better known than other New World groups. Through contact period chronicles, Coe has reconstructed a fascinating picture of how these prehistoric Americans ate.

AMERICA'S FIRST CUISINES, by Sophie D. Coe. *University of Texas Press, $35.00 ($14.95 paper); 276 pp., illus.*

Prehistoric Mexicans made a protein-fortified bread by soaking and cooking maize, a process known as nixtamalization.

Coe begins with a summary of the ingredients available to each of her three groups. The list of domesticated animals is surprisingly short. In Mesoamerica it included only dogs, turkeys, honeybees, and Muscovy ducks. South America had dogs and Muscovy ducks, llama and alpaca, and the guinea pig. Wild animals were extensively utilized by all three New World cultures (game, remember, was also important in the cuisine of fifteenth- and sixteenth-century Europe), but in terms of foods they produced, these societies were mainly dependent on things that grew in the ground.

The New World's staple grain, grown from southern Canada all the way down to the southern reaches of the Inca empire in central Chile, was maize. Maize is just another name for what people in the United States call corn, but because *corn* is sometimes used to describe other cereal grains, the stuff that grows as high as an elephant's eye in the fields of Oklahoma is in Coe's book called maize. Whatever its name, this was the most important item in Aztec, Maya, and Inca diets. Infants were weaned on maize, and many aboriginal

Americans ate it virtually every day of their lives.

Maize was not the New World's only staple food. In the humid tropics, manioc (cassava root) was processed into starch and then made into a sort of bread. It was an everyday food in a good part of the Central and South American lowlands, although the Spanish were unimpressed with the product. ("He had a bit and gave it to us to try," wrote one chronicler, "and we thought it was terrible.") Potatoes and similar root crops—sweet potatoes, yams, oca, ullucu, maka, and llakhum—were staples in the highland Andes, particularly at elevations where maize didn't grow well. In all these regions, however, maize was the staple of choice.

An impressive variety of fruits, greens, seeds, and vegetables supplemented maize and root crops. Beans, squash, and tomatoes are the most famous of these New World products, but the original Americans also domesticated pineapple, passion fruit, avocado, jicama, peanuts, quinoa, and a host of less familiar foodstuffs. In addition, New World cuisines were the source of three of the modern world's most important flavorings: chocolate, vanilla, and chili peppers.

Although these pre-Columbian peoples produced the bulk of what they ate, they were also energetic gatherers. The Aztecs ate cactus fruits and the young pads of the nopal, or prickly pear cactus. They collected water bugs and their eggs, maguey worms, freshwater algae, and the maize smut fungus, *huitlacoche*, which despite its unappetizing name in English is actually quite tasty. According to one chronicler, the Maya would eat anything that didn't smell bad to them. The Inca were

The Incas used llamas to transport maize and potatoes to state warehouses.

also adventurous eaters: seaweed, toads, lupine leaves and seeds, caterpillars, nasturtium blossoms and roots, mayfly larvae, dried lizards, and so many kinds of greens that the chronicler Garcilasco de la Vega (1539–1616) declined to even list them.

Coe supplies fact or anecdote about many of the ingredients. "Columbus was the first European to eat a pineapple, which he did on November 4, 1493." "The word *tomatl* in Nahuatl, the language of the Aztecs, means something round and plump." Drinking cups have been found in Maya burials with the glyphs for "chocolate" written on the vessels' rims. During one of their festivals, the Aztecs spread turkey eggshells on the streets, celebrating "the goodness of the god who had given them that fowl."

The book is most interesting, however, when the author goes beyond the ingredients and talks about cuisines. She focuses her discussion on the features of pre-Columbian cuisines that are most unfamiliar to us. First, because the notion of a staple food has disappeared from our own cuisine, she repeatedly emphasizes the degree to which the Aztec, Maya, and Inca societies built their menus around maize. Maize was eaten green, ripe, and dried. It was soaked, crushed, ground, and fermented; baked, boiled, roasted, steamed, and popped. It may not literally have been used in every dish, but when it was available maize seems to have appeared in every meal.

A second characteristic of these cuisines is that almost everything was flavored with chili peppers. Readers who have traveled in Mexico or Peru will be aware of how important hot peppers are in these countries, but until you have watched people shake ground chile on coconut and pineapple, eat chicken or turkey in chocolate and chili pepper sauce, and chew up whole peppers that are too hot for you to even touch, you may have difficulty appreciating that simple truth. Even the statement that prehistoric Native Americans "ate nothing without them" seems inadequate. But Coe makes this point memorably by reporting that for the original inhabitants of highland Mexico "the simplest fast...was to abstain from salt and chili." The Spanish may have viewed chiles "as a mere condiment," but to pre-Columbians they were "a dietary cornerstone, without which food was a penance."

America's first cuisines, in contrast to the cuisines of Europe and to modern cuisines in general, were low in fats. Pre-Columbian diets included little meat (in the case of the Maya, so little that European observers "described Maya life as perpetual Lent"), and what meat the people got tended to be lean. Squash seeds, cacao beans, peanuts, and avocados are all good sources of vegetable oils, but these were dietary supplements rather than staples, and no pre-Columbian society seems to have extracted edible oils from such sources. In addition, the diets of conquered and conqueror alike were different from our diets today in that the conquest-era cuisines regularly included starchy liquids.

A "class of foodstuff that is extinct in our lives today," writes Coe about the starch-based drinks that the Aztecs called *atolli,* was "sold from shops full of jars large and small, on the street corners as well as in the market." She lists more than a dozen variants of this beverage, differentiated by how the basic maize was prepared and what kinds of flavorings or fortifiers were added. The Maya mixed soured maize dough with water to make *posolli*, and also made as many kinds of *atolli* as their highland neighbors. Andean peoples made maize-based drinks called *chicha* and drank such liquids almost exclusively. Of pure water, a seventeenth-century historian of the Inca Empire, Bernabe Cobo, commented that "there is no greater torture for [Andean Indians] than to make them drink it, a punishment which the Spaniards inflict on them occa-

sionally, and which they feel more than blows."

Two other features of Aztec cuisines deserve to be mentioned here—cacao-based drinks and cannibalism. Coe argues persuasively that both were more important in ritual contexts than as regular dietary items. The case she makes is too wide-ranging to recapitulate in a few sentences, but two features of their preparation and use are striking. Among the Aztecs, only the men were allowed to drink chocolate. And *tlacatlaolli*, or human stew, was one of the only Aztec dishes not flavored with chili. This feature, Coe comments, "should signal to us that this was not an ordinary meal but a religious rite."

Coe does not use modern ethnographic or culinary studies in her reconstruction of the cuisines that existed in late fifteenth and early sixteenth century New World societies. This is a wise decision. Much can be learned from such sources, but distinguishing introduced patterns from indigenous ones is a difficult business. Important elements of the aboriginal cuisines have disappeared (chocolate drinks in the Aztec and Maya regions and wild greens in all three regions are the most obvious examples), and European ingredients and cooking techniques have spread into every cuisine in Latin America.

Still, I wish she had touched more upon the archeological evidence. Pictures of the more obscure fruits and vegetables and an appendix summarizing Latin, common, Spanish, and Indian names for the various foods and plants discussed in the text would have also been helpful.

The strengths of *America's First Cuisines*, however, far outweigh any such complaints. This book is full of significant insights and interesting asides about the cuisines and cultures of the New World's three major indigenous civilizations, and it is as entertaining as it is informative. The European conquest of the New World was a catastrophe for the societies Coe discusses, a cataclysm so fundamental that it even changed the way they ate. But the changes went both ways. The barbecue, baked beans, and corn on the cob in our own cuisine were adopted or adapted from the cuisines of America's indigenous peoples, and understanding where these foods came from makes them even more enjoyable to eat.

A freelance book critic and enthusiastic eater, John R. Alden has done archeological research in Mexico, Panama, Peru, and Chile.

A Prickly Encounter

Photograph by Barrie Wilkins

On one of his early morning drives through South Africa's Kalahari Gemsbok Park, photographer Barrie Wilkins encountered two adolescent lions worrying an African porcupine and her youngster in the dry bed of the Nossob River. Realizing that these burrow-dwelling porcupines are rarely active in the daytime, Wilkins concluded that the lions must have detained the pair all night, trying to get past the sharp, barbed quills to a tasty meal. He also noticed numerous tracks that had been made during scuffles and near-escapes. After observing and photographing the confrontation, he returned to camp. There, members of a research team confirmed that they had seen the animals

in the same place the previous night.

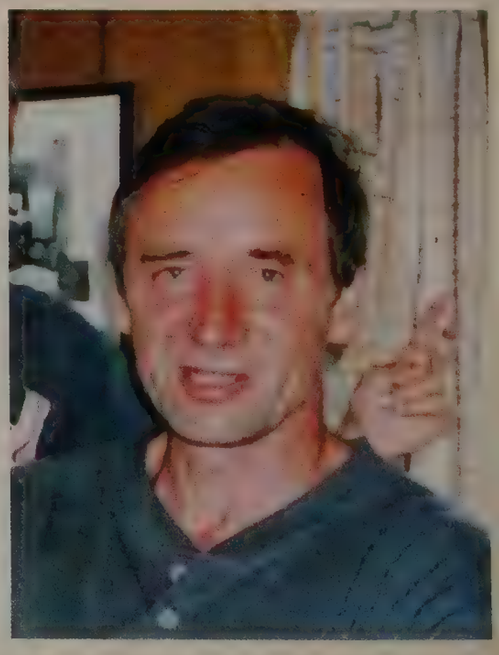
During the two hours Wilkins spent photographing them from his van, one of the young lions kept trying to flip the smaller porcupine so as to reach its unprotected belly. The porcupines, however, always managed to keep a row of quills pointed at the inexperienced lions, no matter which way they circled. (An older lion might have been able to distract one so that his partner could flip the other over.) Suddenly, the mother porcupine charged one of the cats, which jumped out of the way to avoid being stabbed. Then the standoff resumed.

The lions occasionally lost interest and strolled away, but whenever the predators had walked a few yards, the porcupines tried to escape across the river bed, and the lions charged back to reengage them. This game continued until midmorning, accompanied by roaring on the part of the lions, and grunting, hissing, and rattling of quills by the porcupines. Finally, with the lions tiring, the porcupines suddenly made a successful break and reached a safe burrow in the dunes.—*R. M.*

South African photographer **Barrie Wilkins** (page 80) has spent many years taking pictures in the Kalahari Gemsbok Park, which is renowned for its lions. He has exhibited his work worldwide and has twice garnered the Photographic Society of America's Medbury Award. The photo in this month's "Natural Moment" is itself a prizewinner, having taken a first place in the British Gas Wildlife Photographer of the Year Competition, organized by *BBC Wildlife* magazine and the Natural History Museum in London. Because the South African National Parks Board prohibits photographers in nature reserves from stalking their quarry on foot, Wilkins prowls the Gemsbok Park in a four-wheel-drive van, with special mobile camera brackets mounted on the window frame. "The vehicle acts as a blind, allowing relatively close access without disturbing the creatures," he writes. Although his first love is the Kalahari, Wilkins has traveled extensively throughout southern Africa and has also photographed Alaska's bears and Yellowstone's winter wildlife. In 1986, he coauthored *Kalahari Safari,* a photographic book on Kalahari wildlife. He continues to evaluate and record the influence of the seasons on the park's animals. The picture was taken using a Canon EOS with a 600 f4 EF L autofocus lens.

As a teen-ager, **Patricia Chapple Wright** (page 44) read Gerald Durrell's books about his adventures with animals, and after graduating from college in the late sixties, she acquired an owl monkey as a pet. Intrigued by its behavior, she was inspired to go to South America to have a look at owl monkeys in the wild. After that experience, primatologist Warren Kinzey convinced her to go to graduate school. Now an associate professor of anthropology at the State University of New York at Stony Brook, Wright is a MacArthur Fellow and international coordinator of a project to conserve the tropical rain forest in Madagascar's Ranomafana National Park. Her own fieldwork in Madagascar has included studies of three species of bamboo lemurs (*see* "Lemurs Lost and Found," *Natural History,* July 1988) and, for the past eight years, the ecology and behavior of diademed sifakas. For more on rain forests, she recommends John Terborgh's *Diversity and the Tropical Rain Forest* (New York: Scientific American Library, 1992). Terborgh has also written a book specifically about Peru's Cocha Cashu Biological Station: *Five New World Primates* (Princeton: Princeton University Press, 1984).

"You try to uncover the logic of nature, and that logic is always the same, wherever you find yourself," writes **Bernd Heinrich** (page 52), referring to the effect of insects on flower evolution. The idea that bees and other pollinators shaped the appearance and diversity of flowers first excited him when he was a graduate student researching insects in a Maine bog. Twenty years later, he relearned the evolutionary lesson when he saw the array of similar-looking red flowers—including a large red buttercup—blooming in the Judean desert near Jerusalem. A professor of zoology at the University of Vermont, Heinrich is a frequent contributor to *Natural History*. His latest book, *In the Maine Woods,* will be published by Addison-Wesley this fall.



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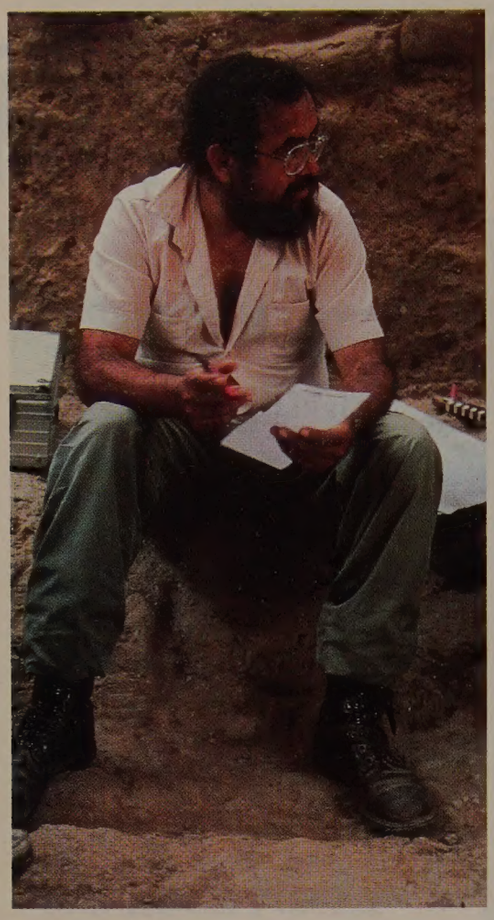
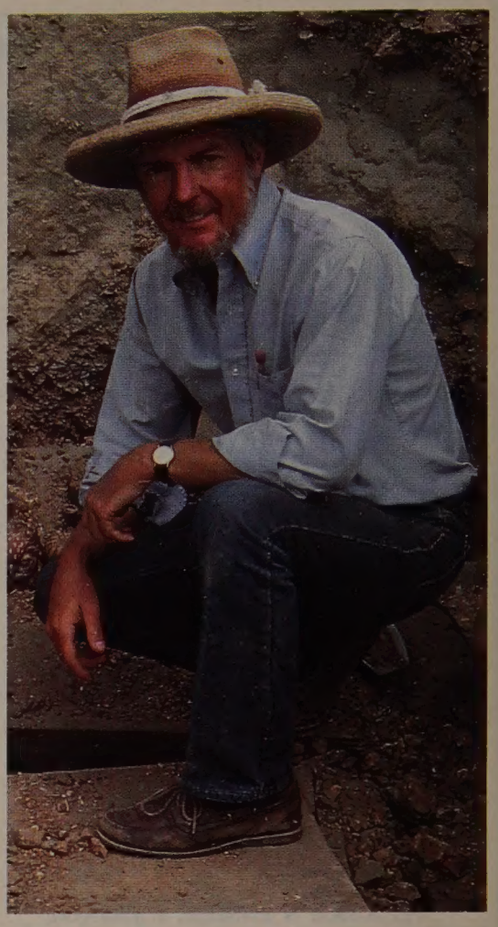
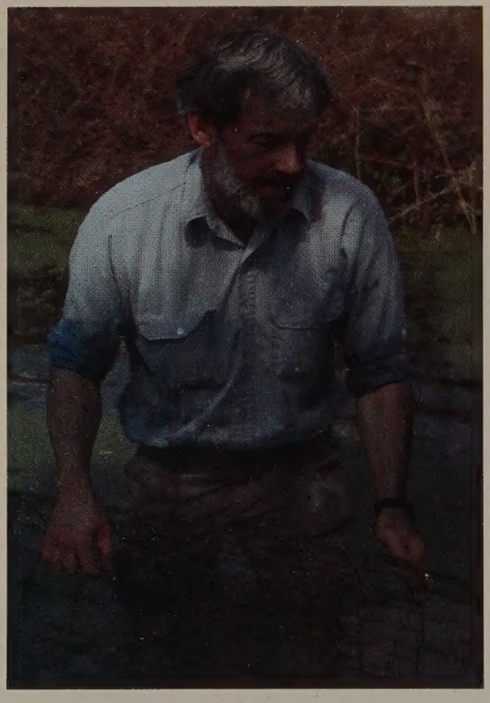


When Peruvian police seized some treasures plundered from a prehistoric pyramid at Sipán, archeologist **Walter Alva** (page 26) was called in to evaluate them. Recognizing that a major tomb had been looted, he organized the subsequent scientific excavations that have so far revealed three intact tombs. A native of Peru, Alva, left, has participated in numerous excavations on that country's north coast and is the director of the Museo Brüning at Lambayeque. Coauthor **Christopher B. Donnan** is a professor of anthropology and director of the Fowler Museum of Cultural History at the University of California, Los Angeles. A specialist in Moche iconography, he participated in the Sipán excavations and worked to identify the priestly ranks of the tombs' principal occupants. Alva and Donnan described the discovery of the tombs and the nature of Moche culture in several articles that appeared in the October 1988 and June 1990 issues of *National Geographic.* They are the coauthors of *Royal Tombs of Sipán* (Los Angeles: Fowler Museum of Cultural History, University of California, 1993).



"I've always enjoyed spending time outside, so pursuit of a graduate degree in field biology seemed a logical way to combine my avocation with a possible vocation," says **Renée Godard** (page 36). Soon to be assistant professor of biology at Hollins College in Roanoke, Virginia, Godard became interested in the evolution of communication as a doctoral student at the University of North Carolina at Chapel Hill. By studying one species, the hooded



warbler, in the field, she began to realize the intricate role song played in the bird's biology. Most recently Godard has been studying a small population of Caribbean flamingos in the Galápagos Islands. Coauthor **Haven Wiley** earned his doctorate in animal behavior from The Rockefeller University in New York. A professor of biology and ecology at the University of North Carolina at Chapel Hill, Wiley has done extensive fieldwork in South America, particularly in Venezuela. But, he says, "In the 1980s, with a growing family, I decided to shift my field research closer to home—and discovered that hooded warblers were among the commonest songbirds in the bottomland forest near the university." This species proved to be an enlightening one in his study of animal communication. Readers can find further information on the behavior and nesting of warblers in Douglass H. Morse's *American Warblers* (Cambridge: Harvard University Press, 1989) and Hal H. Harrison's *Wood Warbler's World* (New York: Simon and Schuster, 1984). *The Selfish Gene,* by Richard Dawkins (Oxford: Oxford University Press, 1990) introduces some of the evolutionary problems associated with reciprocity.

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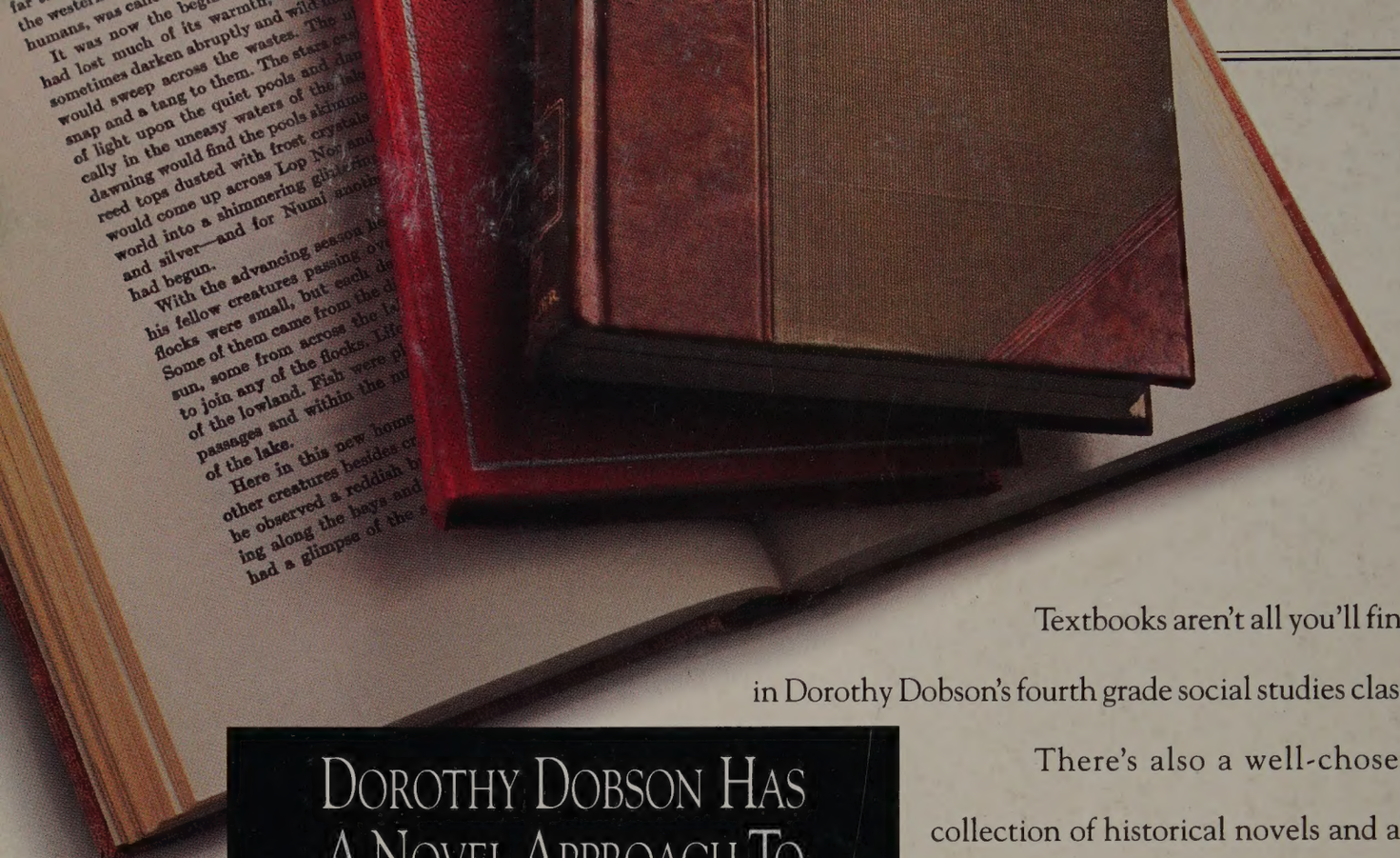
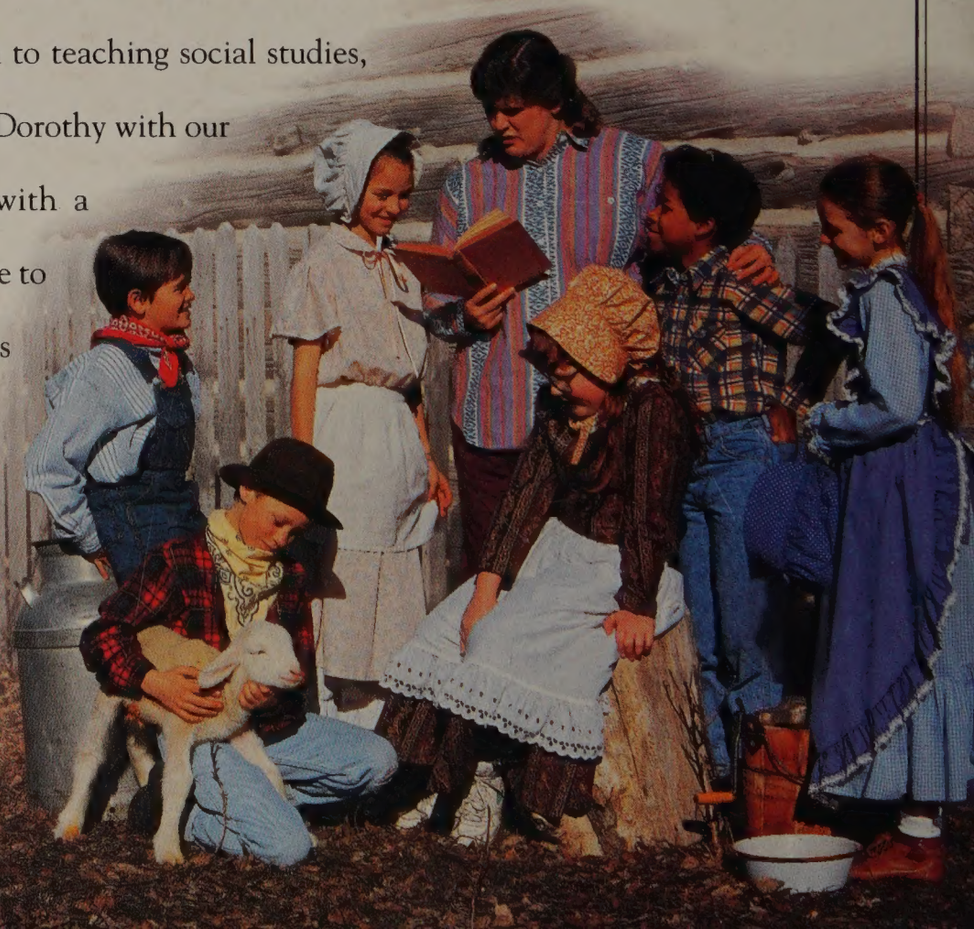


Dorothy Dobson Has A Novel Approach To Teaching Social Studies.

Textbooks aren't all you'll find in Dorothy Dobson's fourth grade social studies class. There's also a well-chosen collection of historical novels and all the space her young students need to bring history to life.

For Dorothy, "memorizing a lot of dates" isn't what's important. Instead, her students read novels that relate to the period of history they're studying. After that, anything can happen. From staged reenactments of important chapters to creating room-length murals that depict historic times and places. In short, any activity that helps them "experience" history.

For her creative approach to teaching social studies, State Farm is honored to present Dorothy with our Good Neighbor Award, along with a contribution of $5,000 in her name to Edith Bowen School on the campus of Utah State University.



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